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PHYSIOLOGICAL PRINCIPLES IN TREATMENT

BY

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PREFACE TO THE THIRD EDITION

Pressure of other work has delayed the appearance of this edition. The lapse of time has necessitated very thorough revision and some rearrangements, involving two additional chapters.

I am indebted to my colleague Dr. Philip Hamill for the electrocardiograms illustrating the chapter on Irregular Action of the Heart.

I should like gratefully to acknowledge the kindly criticisms which the former editions received in the medical press and in private letters; and I have gladly availed myself of many of the suggestions contained therein.

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August, 1914.

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FROM THE PREFACE TO THE FIRST EDITION

In the last decade our ideas have undergone fundamental alterations on many points of cardinal importance in physiology. The same period has seen a much wider use of exact scientific methods in clinical work. The result has been a closer harmony between physiology and practical medicine. The researches of Pawlow and his followers, which have led to the rewriting of the physiology of digestion, the clinical applications of Gaskell's work on the heart by Mackenzie and others, the introduction of convenient methods of registering blood-pressure in man, the increased knowledge of the chemistry of uric acid and its congeners, of nitrogenous metabolism and internal secretion, are examples which will occur to anyone.

The busy practitioner is aware that the physiology of his student days has been largely supplanted or supplemented, but has not time to acquaint himself with the changes, nor to deduce therefrom the points on which his clinical conceptions should be modified.

This book does not aim at being a complete treatise

on applied physiology; but as it has been my lot during the decade in question to combine the practice of medicine with the teaching of physiology, I have set down here some of the considerations which I think have helped me, in the hope that they may help others. . . .

Though the days are past when the student entering the wards often received the superfluous advice to ' forget his physiology,' the physiologist is still regarded a little suspiciously at the bedside. Perhaps he is in part himself to blame for that, for he is sometimes inclined to forget that observations made in the laboratory are not infallible, and are not necessarily more correct than clinical evidence. When I reflect that I am now teaching the exact opposite to many of the views held ten years ago, I feel that physiology can only come to the aid of medicine with becoming modesty, and without overweening dogmatism. There is no finality about either, but that they can co-operate usefully I trust the following pages serve to illustrate.

W. LANGDON BROWN.

October, 1908.

CONTENTS

CHAPTER		PAGE
I.	THE PRINCIPLES OF ORGANO-THERAPY	1
II.	THE RATIONAL TREATMENT OF GASTRIC DISORDERS	43
III.	MECHANICAL FACTORS IN INDIGESTION	92
IV.	THE WORK OF THE PANCREAS	128
V.	URIC ACID AND THE PURIN BODIES	153
VI.	OXALURIA, PHOSPHATURIA, AND URINARY CALCULI	171
VII.	ALBUMINURIA AND THE TREATMENT OF NEPHRITIS	187
VIII.	GLYCOSURIA AND DIABETES	210
IX.	ACIDOSIS AND ACID INTOXICATIONS	232
X.	INTESTINAL INTOXICATIONS	256
XI.	IRREGULAR ACTION OF THE HEART	285
XII.	THE VASOMOTOR SYSTEM IN DISEASE	320
XIII.	ON CYANOSIS	352
XIV.	VITAMINES AND CALCIUM SALTS	365
	PRINCIPAL REFERENCES	382
	INDEX OF SUBJECTS	392
	INDEX OF AUTHORITIES	405

PHYSIOLOGICAL PRINCIPLES IN TREATMENT

CHAPTER I

THE PRINCIPLES OF ORGANO-THERAPY

Whenever we give a drug, we imply thereby a belief that the functions of the body can be influenced by chemical means. And we can find support for this confidence in the fact that the body itself produces chemical substances whereby it regulates its own functions.

Nothing could be more reasonable than to use intelligently in disease those very drugs by which the body is enabled to do its own work in health. This is the basis of a rational organo-therapy, as Starling has so clearly indicated.

Though the use of organic extracts has enormously increased during the last decade, it is but the renaissance of a very ancient method. Celsus and Galen testify to the antiquity of organo-therapy. The first Pharmacopœia, published by the College of Physicians

in 1618, contains several preparations of animal extracts.

The success of thyroid extract in treatment led to a great revival of interest in the subject, an interest not always intelligently displayed. Indiscriminate use of gland extracts in every sort of disease, without consideration of the underlying principles, only brings discredit on a valuable method of treatment. There is no scientific sanction for the employment of brain extract in insanity, and extracts of bronchial glands for phthisis. Powdered heart muscle was a favourite prescription in the old days; it is no advance to squeeze it into a tablet and call it cardin.

In the past it has been too much the fashion to look upon the different organs as largely independent of each other, though under the suzerainty of the brain. But the development of a nervous system is a comparatively late event in evolution. The stimuli to which the most primitive forms of life respond are chemical; the nervous system enables very rapid reactions to occur, but where less sudden responses are needed the primitive method is retained.

Thus, salivary secretion may occur before the food enters the mouth; and though gastric secretion is started by the taste of the food, its continuance is due to chemical stimuli, while pancreatic secretion can be explained by chemical factors alone. Here we note a gradual transition from a nervous to a chemical method of stimulation, as the need for rapidity of response grows less. This is a good example of the

way in which the nervous system may start a series of events, though the subsequent chapters are due to chemical interactions, one organ producing a chemical substance necessary as a stimulant to the next in series.

For these substances Starling suggests the name 'hormones' (ὅρμαω, 'I excite'). Internal secretions owe their activity to hormones. The following table (slightly modified from Starling) gives some of the more recognized of these:

Origin.	Hormone.	Reacting Organ.
Thyroid.	Iodothyrin.	Nervous system, skin, etc.
Suprarenals.	Adrenalin.	Sympathetic nervous system.
Pituitary body.	Pituitrin.	Plain muscle, etc.
Stomach (pylorus).	Gastric secretin.	Stomach (fundus).
Duodenum.	Secretin.	Pancreas. Liver.
Pancreas.	Pancreatic juice.	Intestine.
Ovaries.	.. ..	Uterine mucous membrane, and mammary gland.

This list could be extended; it is, indeed, difficult to decide where the line should be drawn, for the chemical products of every organ must influence the rest of the body to some extent. But it is only when that influence is specific that we dignify the product with the status of a hormone. Thus, carbon dioxide is a product of all the tissues, but has a specially stimulating effect on the respiratory centre, while kreatin, which is formed by muscular tissues, increases gastric secretion and

stimulates growth. Such reactions differ in degree rather than in kind from those of iodothyrin and adrenalin.

Abrahams classified thus the inherent apparatus by which the body can defend itself when attacked:

1. *The physiological reserve*, primarily to combat exhaustion. This is called up in any condition of unusual strain, cardiac hypertrophy being a typical example.

2. *The biochemical apparatus*, which enables one tissue, when attacked, to appeal to another for assistance.

3. *The nervous mechanism*, which, as we have seen, is the latest in evolution, and the swiftest and most complex in its action.

The most essentially vital acts are subserved by a double mechanism. Thus, in heart diseases it is to the physiological reserve and the nervous mechanism that we look, while in digestive disturbances we must rely on the biochemical apparatus and the nervous system. In organo-therapy we are calling the biochemical apparatus to our aid.

Now, the substances which produce effects upon the body fall into two groups (Ehrlich). The first are closely allied in their chemical character to proteins, such as the toxins; all are produced by the agency of living organisms. As a result of their introduction, the tissues react by development of an antibody, and are therefore called ' antigens.' The second group include all the common drugs, which probably act on proto-

plasm by reason of their molecular configuration, producing their effect, without any incubation period, as soon as they reach the cells. Although repeated doses can set up a certain degree of tolerance, they never give rise to the production of an antibody.

We should expect hormones to belong to the second class, because if they excited the production of an antibody, larger and larger doses would be required to effect their physiological purpose, which would defeat their own object. In other words, they belong to the permanent, and not to the acquired, defences of the body.

The general features of hormones may be stated thus:

1. They are bodies of comparatively small molecular weight.

2. Unlike ferments, they are not destroyed by simple heating, but may lose power on prolonged boiling.

3. They are rapidly destroyed by oxidizing agents.

4. They are destroyed in the tissues which they excite, and do not escape in any of the excretions.

5. They are not as a rule absorbed unaltered from the alimentary canal. Iodothyrin, the active principle of thyroid extract, is an exception to this rule, probably because the thyroid gland originally discharged its secretion into the alimentary canal by the thyro-glossal duct.

Hormones are employed in treatment—

1. In substitution therapy—*i.e.*, to replace the absent or deficient secretion of a gland that is involved in a destructive lesion—or where there is relative insuffi-

ciency owing to overaction of some antagonistic gland. Here the hormone is intended to produce a chronic effect.

2. Where their known physiological action may be useful quite apart from any defect in the patient's own glands. Here a sudden effect is usually aimed at.

3. In a purely empirical manner.

For successful substitution therapy the gland from which the extract is prepared must contain the hormone in an amount much in excess of the body's immediate needs, while the hormone must be fairly stable so as to resist chemical changes during extraction, and be capable of absorption from the alimentary canal. Also it must be possible for intermittent doses to replace satisfactorily the constant slow secretion which normally occurs. As Dale points out, the thyroid is the only ductless gland which fulfils all these criteria. For the rest the principal successes have been confined to conditions where the hormone can be used locally or by injection, and where a sudden rather than a prolonged effect is required. Fortunately, hormones are not destroyed by boiling, so they can be prepared in sterile solutions suitable for injection.

The Thyroid Gland and Iodothyrin.

Organo-therapy won its first and most conspicuous triumph with thyroid extract. The ease with which thyroid preparations are absorbed from the alimentary canal has greatly contributed to this, but at the outset

it was not realized that so simple a method would be effective, and subcutaneous injections were employed.

The only active principle that has been isolated from the gland is iodothyrin, a substance rich in iodine and nitrogen, prepared from the colloid in the vesicles by artificial digestion. It is uncertain whether this is the only active substance in the gland, as its effect upon metabolism is less than that of an extract of the whole gland. The presence of iodine, which is a striking peculiarity in this hormone, is interesting in view of the empirical use of iodine in diseases of the thyroid. But the iodine in the gland seems to vary in amount in different animals, and appears to be absent altogether in cattle.

From its great success in myxœdema and cretinism, we may regard iodothyrin as a hormone with a specific action on the central nervous system and on the skin and subcutaneous tissue. These points are familiar to all. The occasional failures in the treatment of myxœdema may be explained thus:

1. In persons of advancing years iodothyrin appears to have less effect.

2. As subjects of myxœdema are more liable to those toxic symptoms known as thyroidism, it is not always possible to give an adequate dose.

While failures in the treatment of cretinism may be accounted for as follows:

1. Successful treatment is only possible before the degeneration of the brain consequent on cretinism has occurred.

2. Errors in diagnosis have led to Mongolian idiots and achondroplasics being treated as cretins.

The effect of iodothyrin on metabolism is to reduce weight, only one-sixth of the loss being due to increased nitrogenous waste, the remainder being due simply to diuresis, apparently from dehydration of fats. It may produce glycosuria. It accelerates the heart-beat without augmenting its force. It is therefore not very effective in the treatment of obesity, and is not free from risk, as a fatty heart may not be able to maintain the accelerated rhythm. Moreover, as in obesity there is often a tendency to glycosuria, the use of a drug which can develop this is inadvisable.

Among the less-known effects of iodothyrin on metabolism is its influence on the liver. Apart from the discoloration, the chief sufferings of a jaundiced patient are due to the toxic effects of the bile-salts; prominent among these is the intense itching, which is sometimes so troublesome.

After ligature of the bile-duct the colloid in the follicles and lymphatics of the thyroid gland increases. Possibly this is a defensive step against intoxication by bile-salts, and accordingly Gilbert and Herscher administered thyroid extract to seven cases of jaundice; in six the pruritus was benefited.

Under thyroid treatment the bile-salts in the urine gradually diminished and then disappeared. After cessation of treatment the reaction returned until thyroid extract was again administered. They concluded that thyroid extract must modify or destroy the

bile-salts. Outside the body they did not find that thyroid has any effect on bile-salts.

Employing Grünbaum's method of estimating bile-salts, I have been able in several cases to confirm Gilbert and Herscher's statement that the administration of thyroid extract diminished the amount of bile-salts in the urine with great relief of pruritus. I have also found that feeding a cat with thyroid gland diminished its production of bile-salts.

The striking changes occurring in the skin in myxœdema implies that iodothyrin plays an important part in regulating its nutrition. Byrom Bramwell therefore employed thyroid extract in various diseases of the skin. The best results seem to have been obtained in psoriasis, ichthyosis, and lupus vulgaris. Its use should be restricted to chronic conditions; Radcliffe Crocker finds that it may excite new lesions if given while the eruption of psoriasis is still developing.

As fractures have been found to heal better in thyroidectomized animals if thyroid extract be given, it has been used to hasten the union of fractures in normal individuals, apparently with benefit. Occasionally the extract appears to delay the growth of a cancer of the breast.

In eclampsia thyroid extract has been advocated, on the ground that in normal pregnancy an enlargement of the thyroid gland occurs, while in the albuminuria of pregnancy or in eclampsia this enlargement may be lacking. As we have seen, some effect on hepatic metabolism must be conceded to the thyroid, and it is

to some hepatic lesion that we must look for the explanation of eclampsia. There is, therefore, a rational basis for this plan of treatment, though it is possible that all the benefits observed can be referred to the diuretic action of the iodothyrin.

Since tetany has been observed after excision of the thyroids and parathyroids in animals, thyroid extract has been employed in its treatment. Tetany may occur after prolonged lactation, and it is quite possible that this is due to the drain of iodothyrin into the milk. At any rate, an infant may develop thyroidism if the mother is taking thyroid extract, so that the drug evidently passes into the milk with ease.

Minor degrees of thyroid inadequacy have been invoked to explain many diseases. No doubt the stimulating effect on metabolism and the vaso-dilator action of iodothyrin is beneficial in conditions where metabolism is sluggish. Leonard Williams reports benefit from this treatment in enuresis. In all such conditions he maintains that the doses usually employed are far too large. He begins with half a grain twice a day and never increases the dose to a point sufficient to cause tachycardia.

Much has been written concerning the function of the parathyroids, and it has been asserted that the twitchings and spasms which have been seen after experimental extirpation of the thyroid, but not in myxœdema, are due to the removal of the parathyroids in the former case, and their escape in the latter. But it is difficult to accept this, in view of the

careful observations of Forsyth on the parathyroids (*Quart. Journ. of Med.*, vol. i., p. 150). These small bodies cannot be detected with certainty by the naked eye; they occur in positions other than those generally recognized; they are more numerous than is commonly supposed; they are not infrequently attached to lymphatic glands, thymic residues, or accessory thyroids; they may be microscopic in size, and, finally, they may be deeply buried in the substance of the gland. To remove them completely must, therefore, be almost impossible. Forsyth concludes that the parathyroids are portions of the main thyroid glands which have not yet formed vesicles. All intermediate stages between thyroid and parathyroid tissues occur. The parathyroids must therefore be regarded as essentially the same in function as the thyroid. There is no satisfactory evidence that the parathyroids bear a pathogenic relationship to any known disease.

The striking contrast between Graves' disease and myxœdema suggests naturally that while the latter is due to an athyrea, the former is due to a hyperthyrea. In Graves' disease the gland is enlarged by an increase in the secreting cells, the excitability of the nervous system is increased, the pulse is rapid, the temperature is raised, the skin is moist, the consumption of oxygen is increased, and there is usually emaciation. In myxœdema the gland is atrophic, the excitability of the nervous system is diminished, the pulse is slow, the temperature subnormal, the skin dry, while diminished oxygen consumption and increase of weight is the rule.

Moreover, the administration of excessive doses of thyroid extract may cause symptoms analogous to those of Graves' disease. If iodothyrin is a hormone acting on the skin and nervous system, Graves' disease can be most readily explained by a hyperthyrea in which the emotional centres undergo an excessive stimulation. Hector Mackenzie has drawn attention to the resemblance between the symptoms of Graves' disease and the expression of the emotion of fear. In both we have the staring eyes, the rapid pulse, and the tremors. It is doubtful, however, whether all the phenomena of Graves' disease can be explained by hyperthyrea alone. Myxœdema following Graves' disease we can understand on this hypothesis, for the gland may become exhausted as a direct result of its excessive activity; but the coexistence of active Graves' disease with some of the symptoms of myxœdema, such as the characteristic condition of the skin, is very difficult to account for. But such cases undoubtedly occur. To say that Graves' disease is due to a perverted rather than an excessive secretion of the thyroid does not carry us much further.

The failure of organo-therapy in Graves' disease is hardly surprising, as we do not really understand the line along which success should be looked for. Thus, if the essence of the disease is a hyperthyrea, administration of thyroid extract could do, and usually does, nothing but harm. The only exception to this is where there has been a compensatory enlargement of the thyroid consequent on inadequate secretion. Here

small doses of thyroid do good. But these are not really cases of Graves' disease. Thus, in a cretin I saw a cystic enlargement of the gland disappear under thyroid extract.

The other organo-therapeutic lines of treatment that have been tried are antitoxic and cytolytic. The hypothesis on which the former method rests is that the blood of a thyroidectomized animal should contain an excess of substances unneutralized by thyroid secretion; these should be antagonistic to a hypertrophied thyroid. But the proof that such substances occur is not satisfactory, and the hypothesis implies an antitoxic rather than a secretory function for the thyroid.

As the rational basis for the use of such preparations is so uncertain, we are prepared for the lack of success that has so far attended the use of Rodagen (a dried preparation from the milk of thyroidectomized goats, with an equal weight of milk-sugar to preserve it), Antithyroidin (a preparation of the serum of thyroidectomized rams, the glands having been removed six weeks previous to the first bleeding), and Thyroidectin (the dried blood of thyroidectomized horses). Lanz and Edmunds have reported benefit from the use of the fresh milk of thyroidectomized goats.

The trial of thyrolytic serum is based on the well-known fact that if a preparation of the cells of one animal be repeatedly injected into the circulation or peritoneal cavity of another animal, the latter will form an antibody capable of destroying those intro-

duced cells. To prepare a satisfactory thyrolytic serum for human thyroids, an emulsion of human thyroids must be employed for the injections. In the analogous case of precipitins, the antibody prepared against dog's blood, for instance, has no effect on ox's blood. This does not appear always to have been borne in mind. But there is another and much graver objection; a serum that will destroy the cells of the thyroid gland in an animal will also destroy the cells of other organs, such as the liver or kidney. In other words, cytolytic sera are not specific for the same organ in different animals, but for all the cells of a particular animal. The treatment is, therefore, at once ineffective and risky.

If there is anything in the antitoxic hypothesis, it is inadvisable, as Hector Mackenzie points out, to give milk and meat from animals in full thyroid activity to patients taking preparations from thyroidectomized animals. The two would tend to counteract each other. Moreover, Chalmers Watson has described hypertrophy of the thyroid as occurring in animals on an excessive meat diet. A reasonable diet in Graves' disease would be fish, chicken, fat bacon, eggs, vegetables, salad and fruit, cream, butter, bread, and carbohydrates generally.

The Suprarenals and Adrenine.

Following on Addison's clinical observations, Brown-Séquard showed that experimental removal of the suprarenals was rapidly fatal to animals. Schäfer and

Oliver in 1893 prepared from these glands an active substance possessed of powerful tonic properties. That this substance was only formed from the medulla of the gland was shown by Swale Vincent from observations on certain fishes in which the cortical and medullary portions are separate glands. Attempts to isolate the active principle from the extract culminated in 1901 in the preparation by Takamine of a crystalline body, to which he gave the name of adrenalin, and to which he attributed the formula $C_{10}H_{15}NO_3$.

Four years later Dakin synthesized it artificially from pyrocatechin, and made a series of similar bodies, showing that their activity depended on the presence of a catechol nucleus. This suggests an origin from the aromatic radicles present in the protein molecule. Its formation in the medulla of the suprarenal is of great interest when we remember that this portion of the gland is developed as a direct outgrowth from the sympathetic nervous system. Nor is this the only example of such an association, for sympathetic paraganglia and structures, such as the carotid body, contain *paragangline*, a similar but more stable body, which does not lose its effect even if left in contact with the stomach wall for twenty-four hours.

Schäfer suggested the name 'adrenine' for the active principle, as most of the other names refer to some particular commercial product.

We owe to Langley the important generalization that the action of adrenine on any part is the same as stimulation of the sympathetic nerves to that part.

It will not act on a structure that at no time in its history has been innervated by the sympathetic. Elliott, in extending these observations, has brought forward some facts which suggest that, after incision of the suprarenals, the muscles innervated by the sympathetic cannot be thrown into activity even by electrical stimulation of the nerves. Adrenine appears, then, to be a chemical body whose presence is essential to the activity of the sympathetic. This is doubly interesting in view of its formation by a structure of sympathetic origin.

In applying adrenine therapeutically we have to consider what would be the effect of stimulating the sympathetic nerves to the part in question. Whether it acts on a 'myoneural junction,' as suggested by Elliott, or on a 'receptive substance' in the cell, as Langley thinks, does not affect this conclusion. The application of adrenine to internal medication is greatly limited by two facts:

1. If mixed with alkalies, its activity is lost; if the alkali be neutralized, the specific effect can be obtained again. Now, as the blood-stream is alkaline, it can only produce a brief general effect through the circulation.

2. It is doubtful whether in healthy persons it is absorbed unaltered from the alimentary canal. The most striking action of adrenine is the rise of blood-pressure that it causes, but many observers have failed to detect any rise when the drug has been given by the mouth. Yet it is not destroyed by gastric juice in a

test-tube. Probably the intense vaso-constriction it produces prevents its own absorption. Rolleston found that, given by the mouth to persons suffering from Addison's disease, it did raise the blood-pressure, though I have often failed to obtain this result. In the same way a myxœdematous person is well known to be much more sensitive to thyroid extract than a healthy individual. Schäfer thinks that injured vessels are similarly more sensitive to adrenine than normal ones, and that a selective vascular constriction may be thus produced even though no general rise of blood-pressure occurs.

It will follow that the drug is most effective when it can be applied direct to the point at which we wish it to act. Even after subcutaneous injection its general effect is much interfered with by the local constriction of bloodvessels, which prevents its entering the circulation until its activity has passed off.

Alimentary Canal.—Since Grünbaum suggested suprarenal extract for hæmatemesis, many instances of its successful use have been reported. I place considerable reliance on ½-drachm doses of the 1 in 1,000 solution of adrenalin chloride in ½ ounce of water, given every three or four hours. Elliott recommends adrenalin borate $\frac{1}{30}$ or $\frac{1}{60}$ grain for hypodermic use, the chloride being painful. In addition to constricting the bleeding-point, it stops peristalsis. If an isolated loop of intestine be placed in a bath of warm salt solution, vigorous peristaltic waves may be seen; the addition of two or three drops of adrenalin solution

to the bath at once renders the coil quiescent. Like the sympathetic, adrenine inhibits the movement of a hollow viscus, while keeping the sphincter controlling the exit closed. Herein lies its advantage over ergotin and the like. For these reasons it will often check vomiting or hiccough, in doses of 10 minims of the 1 in 1,000 solution diluted with water.

It should be tried in intestinal hæmorrhage, though it is open to doubt whether the drug can get past the pyloric sphincter. Graeser succeeded in checking severe intestinal bleeding in typhoid fever by giving three hourly doses of 30 minims of the solution by mouth where ice, opium, ergot, and bismuth had all failed. I have used it in this way with satisfactory results. It may be added also to an enema of starch and opium. As a precautionary measure I give a similar dose about a quarter of an hour before getting the bowels opened by enema after an intestinal hæmorrhage. By keeping the bloodvessels of the small intestine constricted, the walls flaccid, and the ileo-cæcal sphincter closed, it affords the ideal condition for emptying the large bowel by enema.

Adrenine has been recommended for gastro-intestinal atony; but in view of its inhibitory action on peristalsis, it is difficult to believe that it could be of service.

Exner found that intraperitoneal injection of adrenine delays the absorption of poison introduced into the stomach or peritoneal cavity; thus strychnine required twenty times as long to produce its toxic effect. This gain of time is most valuable, and suggests the admin-

istration of a full dose of adrenine pending the employment of other remedies.

Heart and Bloodvessels.—Adrenine is a powerful stimulant to the heart, augmenting its action like the sympathetic; but, as we have seen, to produce this effect it must be injected intravenously. We must remember, however, that as it also constricts the bloodvessels, thereby raising the pressure, it may stimulate the cardio-inhibitory centre in the medulla, so that slowing of the heart through the vagi might be caused instead. Though this might perhaps be prevented by simultaneous injection of atropin, this would merely mean that a way of escape from the excessive pressure would be barred. The sudden vaso-constriction greatly increases the work of the heart, and if this cannot be met, dilatation of the cavities may occur. Dilatation and vagal inhibition are dangers that would outweigh any advantage to be derived from the stimulating effect of the adrenine. The safest thing to do is to give amyl nitrite at the same time, unless the blood-pressure is already low; this will flush the peripheral vessels, thus avoiding the extra work and the stimulation of the cardio-inhibitory centre, though not entirely eliminating the rise of pressure. The action of both drugs is about equally sudden and transitory. I regard 10 minims as the maximum dose that should be employed intravenously at one time. Fortunately, it has been shown experimentally that adrenine does not constrict the coronary vessels, for if it did it would almost certainly produce anginal attacks. In cases of

shock, where the blood-pressure is lowered from dilatation of the splanchnic bloodvessels, adrenine is free from these risks, so that the amyl nitrite is unnecessary. And 'heart failure' in toxæmia is often really due to vasomotor paralysis, so that adrenine may be very useful in such cases, if its mode of action is duly borne in mind. I have seen great improvement follow intravenous injections for the collapse of toxæmic states, especially pneumonia, as Rolleston has found. Elliott and Tuckett's observation that in one toxæmic condition, diphtheria, the chromogen in the medulla is deficient may afford an explanation of these facts. Crile showed experimentally that in the most profound shock it was possible to keep up the blood-pressure and maintain life by the continuous intravenous infusion of adrenalin in salt solution, 1 in 50,000 to 100,000. In the collapse of chloroform or opium poisoning it has also been found useful, though Schäfer has not found it possible to revive the cardiac muscle permanently in this way.

Butler has recorded an example of its striking success in syncope after the crisis of pneumonia in a child of ten. He injected 38 minims in all in five doses, besides giving 10 minims by the mouth. He says: 'No words of mine can express the absolutely marvellous nature of the change in the child's condition due to the drug.' He reports a very significant fact, however: 'Each time it was noticed what was most apparent after the initial large injection—namely, that the immediate effect was an increase of pallor and a

weakening of the pulse, followed by great and rapid improvement.' Evidently, in the doses here used the immediate rise of blood-pressure was enough to act on the cardio-inhibitory centre in the way I have pointed out.

In accordance with the general law that adrenine only acts on structures which have a sympathetic innervation, Baum found it had no effect in blanching nævi, and only a very transitory effect on unsound flesh.

Respiratory System. — A paroxysm of *asthma* may often be cut short by the subcutaneous injection of 5 or 10 minims of a preparation of adrenine, such as the liq. adrenalin hydrochlor. Like many such remedies, however, it may tend to increase recurrences and may gradually lose its effect. As the vagus and sympathetic are opposed in their action, and as the former is constrictor in its effect on the bronchial muscles, the latter might be expected to inhibit bronchial spasm. It would, moreover, constrict the turgid vessels in the bronchial mucosa. Both these actions would be produced by adrenine.

In the chapter on the Vasomotor System in Disease, it is pointed out that the changes in the pulmonary circulation are passive, and are controlled by the systemic circulation. On perfusion of adrenine through the pulmonary vessels Brodie and Dixon could not find any evidence of vaso-constrictors, a conclusion with which most subsequent observers have concurred. I have seen the thoracic viscera from an animal killed by a fatal dose of adrenine; while all the

other tissues were anæmic, the coronary vessels were distended with blood, and the lungs were intensely congested, being a deep plum colour. I therefore cannot believe that adrenine is advisable in *hæmoptysis*. In so far as any result is obtained it will be a harmful one. The blood which is being squeezed out of the rest of the circulation will be forced into the pulmonary vessels, which are unable to protect themselves by adequate vaso-constriction, and hæmorrhage will be aggravated unless the sole source of the bleeding is a bronchial vessel. The only reason why serious harm has not been done more frequently is that the drug has been administered by the mouth, so that it has had little effect; but if injected into the circulation, it would have an injurious effect in hæmoptysis, because of the pulmonary engorgement that results.

Cerebral Hæmorrhage.—For similar reasons adrenine is contra-indicated in cerebral hæmorrhage. Even admitting that there are vaso-constrictors in the vessels of the brain (and Wiggens found a slight constriction after perfusing adrenine), the systemic rise of blood-pressure certainly outweighs any possible advantage to be reaped from a local constriction in the cerebral vessels; and local application is out of the question.

In **hæmophilia**, Schlesinger has given adrenine in doses of 10 to 20 minims by the mouth for intestinal bleeding with success. Improvement has followed its use in **purpura**, though it is difficult to imagine how small doses of a drug which is probably not even absorbed from the stomach could affect hæmorrhages

resulting from an altered condition of the blood. I have not been able to satisfy myself that the improvement was more than rest and suitable diet could account for. Dudgeon has suggested, however, that purpura may stand in the same relation to acute lesions of the suprarenals as pigmentation does to chronic destruction, a view which would make adrenine the proper treatment. It is true that acute lesions of these structures such as hæmorrhage or necrosis are commonly accompanied by a purpuric eruption.

Serous Membranes.—Injection of adrenine to prevent recurrence of ascites or pleural effusion has been advocated by Sir James Barr. A drachm of the adrenalin chloride solution in 2 drachms or ½ ounce of sterilized water is injected through the trocar when the serous exudation has been withdrawn. Plant and Steele suggested that it acts by sticking the layers together, thereby promoting adhesions. I have seen abundant fibrous coagula in the peritoneal cavity post-mortem following this treatment.

I have not had any bad effects such as pain and a rise in temperature where I have used it with ½ per cent. solution of chloretone. The treatment seems free from risk and worth trying. But the most that can be claimed for it in ascites is that it delays return of the fluid.

Surgical Applications.—Adrenine has been very useful in certain surgical conditions, but on these I shall only touch briefly. For removal of foreign bodies and other operations on the eye, Darier recommends 10

drops of the 1 in 1,000 solution added to 10 grammes of a 1 per cent. solution of cocaine. MacCallan thinks it is risky in glaucoma, as he has seen it cause a rise in tension. I saw an alcoholic patient who was in the habit of dropping adrenine into his eyes to diminish their bloodshot appearance, but the secondary reddening that followed the temporary constriction had left him in a worse plight than before.

Its blanching action has rendered adrenine of considerable service both for diagnosis and treatment of diseases of the nose, for it is rapidly absorbed by the nasal mucous membrane. For similar reasons it is a palliative in hay fever.

In affections of the bladder it has been used with cocaine for anæsthetic purposes. Duncannon reports favourably on its use in catheterization, in the pain and strangury of acute gonorrhœa, and in the hæmaturia of enlarged prostate. In the form of ointment it certainly seems to alleviate hæmorrhoids. In uterine bleeding it may be looked to to produce a double effect, constricting the bleeding vessels and causing contractions of the pregnant uterus. Cushny and Dale have shown the curious and interesting fact that adrenine relaxes the non-pregnant and contracts the pregnant uterus. Such contractions are, however, inadequate to induce labour.

In **local anæsthesia** the rôle of adrenine is to prevent the escape of the anæsthetic from the field of operation by constricting the bloodvessels in the neighbourhood. In this way its general toxic effect is diminished, while

its local anæsthetic effect is increased. It has been proved experimentally that whereas of a subcutaneous injection of lactose one-third is excreted by the urine in the first hour, if two drops of adrenine be added, none is excreted in that time, showing that it had not left the site of injection. In using adrenine in this way it must be remembered that cocaine, novocaine, and alypin either have no influence on its action or slightly increase it; while eucaine, tropocaine, and possibly stovaine, are markedly antagonistic, considerably decreasing its activity.

It is important that there should be no trace of soda in the fluid used for boiling the syringe employed, since adrenine is rapidly destroyed in alkaline solutions.

B. T. Lang recommends the following three solutions of different strengths, but all, as far as possible, isotonic with blood:

	A. 0·4 per Cent.	B. 0·8 per Cent.	C. 2 per Cent.
4 per cent. novocaine with 0·1 per cent. thymol with oil of gaultheria	1 c.c.	2 c.c.	5 c.c.
4 per cent. saline with thymol and oil of gaultheria	2 c.c.	2 c.c.	2 c.c.
1 in 1,000 adrenalin with thymol and oil of gaultheria ..	3 drops.	3 drops.	3 drops.
Distilled water up to	10 c.c.	10 c.c.	10 c.c.

The most dilute solution is for fine nerve terminals; the larger the nerve trunks to be anæsthetized, the stronger should be the solution employed.

It is impossible to anæsthetize satisfactorily any

inflamed tissue by immediate infiltration, as the intercellular spaces are already filled with lymph, but it may be possible to attack the nerves supplying the inflamed area nearer the brain.

In spinal anæsthesia adrenine is not so satisfactory, as it limits the spread of the injection too much. Also its use has been followed by petechial hæmorrhages in the brain, which may well be due to the blood being driven to a part which is unable adequately to protect itself by vaso-constriction.

Adrenine and Addison's Disease.—Wilks' view of the 'unity of Addison's disease' now admits of restatement. It is due to the absence of adrenine from the circulation, and this may be brought about in several ways. We can reconcile the two views originally held as to its pathology—one ascribing it to fibro-caseous change in the suprarenals, the other to changes in the adjacent sympathetic.

If the sympathetic cannot act in the absence of adrenine, two of the cardinal symptoms of Addison's disease are explained. As the sympathetic supplies accelerator fibres to the heart, and constrictor fibres to the bloodvessels, their paralysis must result in profound cardio-vascular atony. The sympathetic also provides the stomach with inhibitory fibres; their loss must lead to motor irritability of the stomach, and therefore to vomiting. This will be intensified because, the closure of the pyloric sphincter being under the control of the sympathetic, regurgitation into the stomach can now easily occur from the duodenum.

For similar reasons, as I pointed out some years ago, it may be impossible to cause reflex dilatation of the pupil by pinching the skin of the neck. I have obtained this reflex dilatation however in Addison's disease only two days before death.

The pigmentation is more difficult to explain. Adrenine, like many other bodies containing the benzene nucleus, is a chromogenic substance, and Hopkins has thrown out a suggestion that the deposit of pigment is due to 'adrenine gone wrong,' as one might say. Rendle Short believes that the pigmentation results from the relaxed condition of the bloodvessels, like the pigmentation after poulticing or exposure to light.

Occasionally the gland is found to have been completely destroyed, and yet the signs of suprarenal inadequacy have not developed. At St. Bartholomew's Hospital, during thirteen years, four examples of caseation of both suprarenals were discovered post mortem which had led to no symptoms during life. Grünbaum suggests that the similar cells in connection with the sympathetic chain have assumed the function of the gland.

It must be admitted that the treatment of Addison's disease by suprarenal extract has so far been very disappointing. Nothing at all comparable to the success of thyroid medication has been recorded. The best results have been in chronic cases, without additional lesions elsewhere.

The probable explanations for this lack of success are these:

1. Unlike the thyroid, which is a reservoir of the active principle, the amount of adrenine in the gland at any moment is very small. This objection will not apply, of course, to cases where adrenine itself is used, and not suprarenal extract.

2. It is doubtful whether adrenine is absorbed sufficiently to be really effective when given by the mouth. We have seen that in the normal individual adrenine causes no rise of blood-pressure when administered thus. It is true that it may produce a rise when given in Addison's disease, presumably because the vasoconstrictors of the stomach are in too atonic a state to respond. Grünbaum claims that this will aid in the diagnosis of Addison's disease. He gives 3 grains of suprarenal extract three times a day for three days. If a rise of more than 10 per cent. occurs in the blood-pressure, he thinks that the probability of Addison's disease approaches a certainty. This test frequently fails.

And in any case, as the tone of the bloodvessels returns, adrenine must defeat itself, causing a vasoconstriction which will render its own absorption increasingly difficult. This is probably the chief reason for the failure of the drug.

3. Repeated intravenous injections are impracticable, and would not really take the place of the steady, continued secretion of small doses into the circulation, such as the normal gland accomplishes.

4. In some cases the patient is suffering from progressive tuberculous lesions, which are not checked by

this treatment. It is possible that in the future paragangline, pituitrin, or the artificially synthesized substances, which are more stable, and therefore more continued in their action, may prove more successful.

The cortex must also have some function. Bulloch and Sequeira have pointed out the connection between premature sexual development and adenomata of the suprarenal cortex (Transactions of the Pathological Society, 1905). They suggest that the cortex may yield a hormone which influences growth of the body and the development of puberty and sexual maturity.

Deleterious Effects.—Like all powerful drugs, adrenine has its dangers. We need not fear these bad results from local application or subcutaneous injection, since the vaso-constriction it produces so greatly interferes with its absorption. They have only been noted after intravenous injection.

1. *Mechanical Effects of High Blood-Pressure.*—The great pulmonary engorgement produced seriously limits the use of the drug as a cardiac stimulant in inflammatory diseases of the lung. As the brain cannot adequately protect itself against this rise of pressure by vaso-constriction, damage may be done here also. The use of adrenine in spinal analgesia has been followed by convulsive seizures, due to petechial hæmorrhages produced in this way.

Repeated injection of adrenine into rabbits has been thought to cause atheroma, aneurysmal dilatations, and hypertrophy of the heart. This accords with the observation that anything causing a persistently high

pressure leads to arterial degeneration. But rabbits are very liable to arterial degeneration without such injections. Philpot also noted an increase in the medulla and chromaffin material in diseases associated with high blood-pressure.

2. *Glycosuria.*—This will be discussed in the chapter on Glycosuria in general.

3. *Toxic Effects on the Tissues.*—Necrotic areas have been found in the centre of the lobules of the liver, outside which were areas of fatty degeneration. They have been attributed to the shutting off of the arterial blood by the intense vaso-constriction. I have seen similar changes in the liver of a child to whom I had given an intravenous injection of 15 minims, but the child had broncho-pneumonia, which often leads to fatty liver. In the kidney, cloudy swelling and desquamation of the tubular epithelium have been seen after injections of adrenine both experimentally and clinically. However, Butler's case, in which as much as 38 minims were injected in all, recovered, so that if the damage be due to the drug it apparently is not permanent.

Summary.—Adrenine, which is formed in the medulla, is a benzene compound probably derived from the aromatic group in the protein molecule. It is not destroyed by simple boiling, but is rapidly destroyed by oxidizing agents, which turn it brown; apparently it is quickly dealt with thus in the tissue it excites. It loses its activity in the presence of alkalies. It is probably absorbed with great difficulty from the ali-

mentary canal. Its application to any part produces the same effect as if the sympathetic nerves to that part had been stimulated. It may be freely applied locally, though some observers think that caution is needed in the case of the nasal mucous membrane and (in old people) the eye. Subcutaneous injections are usually safe, though repeated injections may cause necrosis in ill-nourished parts from the local anæmia it produces. Intravenous injection is the only method of producing a general, as opposed to a local effect, and this is not free from risk. The best results have been obtained in cases of bleeding from any part of the alimentary canal, but it is also useful in asthma, in vomiting, and in preventing the absorption of poisons. It is contra-indicated in hæmoptysis and in cerebral hæmorrhage. It may be used to delay the return of serous exudates, and is an adjuvant to local anæsthesia. In Addison's disease it is disappointing.

The Pituitary Body (Hypophysis Cerebri) and Pituitrin.

In its double origin—in part nervous, in part epithelial—this structure offers an interesting parallel to the suprarenals. The glandular lobe is larger and anterior, the nervous lobe is smaller, posterior, and connected with the floor of the third ventricle by a stalk. The glandular portion also surrounds the posterior lobe by the pars intermedia. The anterior lobe forms a colloidal secretion rather like that of the thyroid, while the posterior portion discharges a substance—

pituitrin, somewhat resembling adrenine in action—into the cerebro-spinal fluid by way of the third ventricle.

The secretion of the anterior lobe appears to have an effect upon body temperature, growth, the cutaneous tissues, and the sexual organs. Thus, after removal of the gland, the temperature becomes subnormal, while the injection of its extract causes a febrile response, either when this lobe has been experimentally removed or when it is diseased. This has been used as a diagnostic method, and administration of anterior lobe extract by the mouth has been used to raise the subnormal temperature in hypopituitarism. If the anterior lobe is removed in the young animal, retrogressive changes are observed in the reproductive organs, while the thymus remains large. The secondary sexual characters fail to develop or are much delayed. Hypopituitarism coming on in the adult is characterized by amenorrhœa in the female and by impotence in the male. On the other hand, in the early active stages of acromegaly there may be undue sexual activity.

Oversecretion of this lobe is accompanied by increase in the thickness of the skin, enlargement of the glands, cutaneous hypertrichosis, and overgrowth of the skeleton, while undersecretion is accompanied by the opposite conditions.

The secretion of the posterior lobe, pituitrin, is mainly a stimulant to plain muscle and to carbohydrate metabolism. It acts on plain muscle more by increasing its sensitiveness to normal stimuli than by

acting as a direct stimulant. It does not usually raise blood-pressure in a normal person, but when pressure is much lowered by shock or by experimental cutting off of the vasomotor centre it has a well-marked and prolonged action. In the same way the normal heart is but little affected by pituitrin, but a failing heart is restored in tone and increased in contractile power. Its action on the plain muscle of a healthy intestine is but slight; it has, however, a markedly stimulant effect on the same muscle when it is paretic, as in post-operative conditions. Pituitrin does not cause contractions of the unimpregnated uterus, nor does it induce labour in pregnancy, but when once labour has begun and the uterine muscle is inert it intensifies and prolongs the pains and decreases the intervals between them (Blair Bell). It dilates the pupil of an excised eye, and causes contraction of the bladder muscles. It is a stimulant to mammary secretion.

It also causes vaso-dilatation in the kidney with consequent diuresis. The effect is not lost by repetition of the injection as is the pressor action. This diuretic influence explains the polyuria which accompanies irritative lesions of the pituitary body, and it is not surprising to find that the symptom known as diabetes insipidus is frequently due to disease of the gland or its neighbourhood, such as a syphilitic meningitis. In every case of diabetes insipidus it is therefore important to have a skiagram of the skull taken and Wassermann's reaction done.

The influence of the posterior lobe on carbohydrate metabolism is shown in the hyperglycæmia, lowered sugar tolerance, or spontaneous glycosuria of the early active stages of acromegaly, or as the result of injection of its extract. In the later stages of acromegaly, when the gland is largely destroyed, this is replaced by hypoglycæmia and a greatly raised tolerance of carbohydrates, so that it is impossible to produce glycosuria by giving very large amounts of sugar, such as 400 grammes. The adiposity which accompanies hypopituitarism is no doubt in part due to this raised tolerance for carbohydrates, which are rapidly assimilated and deposited as fat. But the sexual hypoplasia is also partly responsible for this adiposity, for it is a familiar fact that castration or spaying results in much of the energy absorbed in the elaboration of the sexual secretions being now diverted to the deposit of fat.

Therefore in the early stages of acromegaly in addition to pressure symptoms on the optic nerves (such as atrophy and bitemporal hemianopsia) and on the brain (such as headache), we find high blood-pressure, lowered sugar tolerance, or spontaneous glycosuria, overgrowth of the skeleton and cutaneous structures, and pressor substances in the urine. In the later stages the blood-pressure falls, the sugar tolerance is high, but the bony changes are permanent. In primary hypopituitarism (Fröhlich's syndrome) the skin is smooth, transparent, and free from moisture, the axillary and pubic hair is scanty or absent, the nails are small and thin, and pigmentation may be present.

The blood-pressure is low, the sugar tolerance is high, there is general adiposity, except, as pointed out by Turney, in connection with the reproductive organs, and there is a general loss of sexual power. In some cases of growths in the gland the symptoms are complicated by the fact that there may be a temporary overaction of the posterior lobe by irritation, while there is deficiency in the normal secretion of the anterior lobe. Moreover, the balance of the internal secretions may become disturbed, so that there is compensatory enlargement of the thyroid or splanchnic stimulation of the adrenals. Some of these points are dealt with further in the chapter on Glycosuria.

In pregnancy there may be temporary overgrowth of the pituitary, so that the facies alters, slightly approximating about the nose and mouth to that of acromegaly.

Substitution therapy with pituitary extract has not been very successful. In active acromegaly it cannot be expected to do good; in pituitary deficiency large doses are recommended by Cushing, such as 12 grains of the dried whole gland three times a day, while as much as 300 grains have been given in a day.

Pituitrin, the hormone of the posterior lobe, has been used successfully for its vaso-constrictor effect in shock, particularly when due to anæsthetics, and as a stimulant in intestinal paresis. It may also be tried as a diuretic. It has also been used with apparent benefit in exophthalmic goitre and intestinal hæmorrhage. Blair Bell, who made the first clinical observations on

the subject, has used it for *post-partum* deficiency of uterine tone. It is doubtful whether it is superior to ergot in this capacity, however, while before delivery its use is subject to the same limitations as that drug.

It is often given by the mouth, but is much more certain in its action when given intramuscularly or intravenously. In conditions of shock the best method is to add it to an intravenous saline. The dose ranges from 10 to 30 minims, and it can be given three or four times a day.*

Other Hormones.

Therapeutical applications of other hormones need be dealt with only briefly. Those concerned with the digestive organs are discussed in other chapters; in the remainder the active principle has not been isolated yet, and until this is done we are working in the dark.

Ovary.—Marshall and Jolly believe that the changes in the uterus which determine menstruation are due, not to ovulation, but to an internal secretion arising from the ovary, probably from its interstitial cells. Extirpation of the ovaries in early pregnancy prevents the fixation of the ovum, and Fraenkel states that the destruction of the corpora lutea by the galvano-cautery is as efficacious as total removal of the ovaries in bringing pregnancy to an end. Now, the corpora lutea are also derived from the interstitial cells of the ovary. It would appear that these provide a secretion which is essential to the activity of the uterine mucosa.

* For further details see the admirable papers of Cushing and his colleagues.

This explains why the corpus luteum persists if pregnancy occurs, but soon atrophies if it does not.

It is possible that extracts of corpus luteum or of interstitial ovarian cells might be useful in those cases where abortion occurs repeatedly in the early months of pregnancy.

In animals where the ovaries have been removed, the phenomena of heat may be reinduced by the injection of ovarian extracts. Ovarian extract has therefore been tried for the relief of symptoms following ovariotomy or at the climacteric. On the whole it has been more successful in coping with the vasomotor disturbances than with the neurotic symptoms. Benefit has been reported from its use in the treatment of melancholia or mania associated with uterine or ovarian disease, and in exophthalmic goitre.

Wherever the efficacy of ovarian extract is being tested, it is important that the patient should be in ignorance of the nature of the drug, in order to avoid the element of suggestion.

How does the mammary gland undergo hypertrophy in pregnancy and become functionally active as soon as pregnancy terminates? No nervous connection has been made out between the uterus and these glands, so that a chemical stimulant is suggested. Starling thought he had found this in the fœtus, but the corpus luteum is more probably the source.

Testis.—The contrast between the condition of a person in whom the testes are undescended and one from whom they have been removed has naturally led

to the opinion that these structures form an internal secretion responsible for the production of the secondary male characters, which persist in the former case.

Shattock and Seligmann found that the occlusion of the vasa deferentia does not hinder the full development of these secondary characters. We must distinguish this, however, from the effect of ligaturing the whole spermatic cord, which would bring both internal and external secretions to an end. They regard the interstitial cells as the probable source of this internal secretion, and it is noteworthy that after ligature of the vas these cells remain unaltered, although the spermatogenic tissue degenerates.

Brown-Séquard believed that subcutaneous injections of testicular extract produced a rejuvenating effect on himself at the age of seventy-two. Here the element of auto-suggestion certainly played a part. Perhaps because of the exaggerated claims made for it, this treatment fell into discredit, which reacted unfavourably on organo-therapy as a whole.

Poehl attempted to place it on a more scientific basis; he prepared from the gland a crystalline substance—spermin—which he regarded as a catalytic agent, increasing oxidation, and thus acting as a powerful physiological tonic. But Loewy and Richter did not find that it altered the oxygen exchange of castrated animals.

Many of the preparations of testicular substance used are rich in organic phosphorus and lecithin. When these factors, as well as that of suggestion, are

excluded, the evidence as to the benefits claimed for them in nervous diseases, psychoses, impotence, and a host of other conditions, shrinks to slender proportions indeed.

Thymus.—The thymus is an infantile organ that tends to disappear spontaneously, and whereas there is an association between the cortex of the suprarenal and sexual development, there appears to be an equally definite antagonism between the thymus and the sexual organs. Thus Henderson found that castration in young cattle delayed the normal atrophy of the thymus, while Paton and Goodall have shown that excision of the thymus in young guinea-pigs was followed by rapid growth of the reproductive organs. No other changes were noted beyond a diminution of the leucocytes, affecting all the varieties, which lasted for two months. The gland is a special infantile organ for forming white corpuscles, which are more numerous in the circulation of the child during the normal period of activity of the thymus. As nucleated red cells have been found in the gland, it is possible that it may form erythrocytes also. No active extract has been prepared from the organ, so there is no evidence that it forms an internal secretion, nor do thymus extracts appear effective in disease.

The enlargement of the thymus in cases of Graves' disease is interesting, in view of the development of both thyroid and thymus from branchial clefts. In one fatal case I found Hassall's corpuscles (usually regarded as remains of the epithelium of the gill-slits)

enormously hypertrophied. As Graves' disease does not occur till after the thymus should have disappeared, its persistence in this disease raises the interesting suggestion that only those who are the subjects of persistent thymus can suffer from Graves' disease.

The association of enlargement of the thymus with sudden death is, strictly speaking, outside our present subject. The enlargement is usually merely the most striking example of a general lymphatic overgrowth, to which the name of 'lymphatism,' or status lymphaticus, has been given. The condition is commonest in infants, though not unknown in adolescents. The subjects are usually plump and flabby, with a pasty complexion. Hypertrophy of the tonsils, perhaps a slight swelling of the thyroid, and sometimes dulness behind the sternum may be detected.

Death may be dramatically sudden, or there may be 'thymic asthma,' followed by heart failure. They succumb readily to anæsthetics; chloroform and ether seem equally dangerous. After a brief administration the patient may go rigid, or have a slight tetanic convulsion, and die forthwith. It is possible that some of the cases of sudden death while bathing are due to lymphatism. There is no doubt that lymphatism is a real condition; the pardonable scepticism which exists as to its reality is due to its being invoked to explain too many misadventures.

Three explanations have been given of the sudden death:

1. *Pressure* on the trachea, the vagus, or its branches.

Flattening of the trachea has been observed post-mortem, and relief of dyspnœa has followed raising of the gland from the trachea by operation. Thymic death is not from asphyxia, however, but from syncope.

Nor could death be due to laryngeal spasm from pressure on the recurrent laryngeal nerves. Such spasm to be fatal must be bilateral, and the right recurrent laryngeal nerve hardly enters the thorax at all. Moreover, there is not the typical crowing inspiration of laryngeal obstruction.

Pressure on the vagus is possible, and would cause syncope.

2. *Intravascular clotting.* An extract of thymus gland will cause intravascular clotting, and therefore sudden death, but this does not represent a normal internal secretion of the thymus, and simply owes its activity to the thrombokinase it contains. Moreover, intravascular clotting is conspicuously absent in cases of ' thymic death.'

3. *Toxæmia.* The general hypertrophy of the lymphoid tissue suggests that the body is reacting to some infective process. The adenoid tissue of children has a great tendency to react to irritation. On this view the death is merely the terminal event of a prolonged intoxication, the nature of which is at present unknown. The toxin is presumed to act on the respiratory and cardiac centres in the medulla.

Kidney.—There is no evidence of an internal secretion formed by the kidney. Rose Bradford observed increased excretion of urea after removal of a con-

siderable proportion of the substance of the kidneys in dogs, which was thought to point to a regulation of nitrogenous metabolism by an internal secretion. Beddard and Bainbridge have shown that this rise in nitrogenous output was probably merely that of the later stages of starvation from any cause. Extracts of kidney have not met with any therapeutical success.

Muscle.—The use of meat-juice (zomo-therapy) in pulmonary tuberculosis, and of meat-extracts to stimulate secretion of acid in the gastric juice, may also be classed as examples of organo-therapy.

Though many other organic extracts have been employed, it cannot be said that they have achieved, or, for that matter, have deserved, success; for the preliminary proof that the extracts contained any active principle whatever has been lacking. Starling looks forward to an important future for organo-therapy conducted on right lines when he says: 'If the mutual control . . . of the body be largely determined by the production of definite chemical substances in the blood, the discovery of the nature of these substances will enable us to interpose at any desired phase in these functions, and so to acquire an absolute control over the working of the human body. Such a control is the goal of medical science.'

Far though we may be from such a goal, the study of hormones offers a profitable field for research. For it is only by an exact knowledge of the bodily processes in health that we can learn to intervene effectively in disease.

CHAPTER II

THE RATIONAL TREATMENT OF GASTRIC DISORDERS

Recent important additions to our knowledge of the digestive processes have modified the rational treatment of gastric disorders.

The Nervous Factor in Gastric Digestion. — We owe the fundamental experiments on this subject to the Russian school of physiologists. Pawlow, by dividing the œsophagus in dogs, and fixing the divided ends to the skin, completely separated the cavities of the mouth and stomach. Food taken into the mouth would naturally drop out of the gullet: this is termed ' sham feeding,' but ' direct feeding ' could also be carried out by passing food into the stomach by way of the lower segment of the œsophagus. In some cases a separate cul-de-sac was made out of a portion of the stomach. This pocket opened on to the surface so that the digestive processes in it could be easily observed; it was found that they were an exact reflection of those occurring in the main stomach.

He found that in such a dog the taking of food by the mouth was followed after an interval of five minutes by a copious secretion of gastric juice; in fact, it was

not necessary for the food even to be swallowed. If the dog were shown the food, secretion would follow, until the animal realized it was not going to get it.

Clearly, a nervous agency must be at work. Now, if one vagus were previously divided below the recurrent laryngeal and cardiac branches, and the other drawn into the wound, the latter could easily be cut while the animal was feeding. It was found that now 'sham feeding' produced no effect. Conversely, if the vagus had been previously drawn into the wound and divided, to allow the cardio-inhibitory fibres to degenerate, stimulation of the peripheral end, too weak to cause the animal any pain, led to a secretion of gastric juice.

On the other hand, 'direct feeding' into the stomach led to hardly any secretion, if the animal did not see the food.

The value of an appetite in aiding digestion was more clearly proved by the following experiment: Two dogs had 100 grammes of meat introduced direct into the gastric cul-de-sac; one dog's attention was distracted, so that he did not know he had received food, while with the other a vigorous 'sham feeding' was kept up at the same time. In the first hour the first dog digested only 6 grammes, while the other digested 30. The difference represents the digestive value of the passage of food through the mouth, and the consequent rousing of the appetite.

The character of the juice poured out varied greatly with the diet that excited it. Thus, a meal of bread

caused the secretion of a small amount of juice, rich in pepsin, but poor in acid. Meat caused a much larger secretion of a juice weaker in peptic power, but containing more acid. Milk required even less pepsin to digest it than meat.

The Chemical Factor in Gastric Digestion. — Mechanical stimulation of the gastric mucosa will lead merely to an outpouring of alkaline mucus, but certain chemical stimuli will result in true secretion. As clinically chemical factors are more under our control than nervous ones, these are of practical importance.

We may arrange the effect of articles of diet as follows:

1. Substances producing a powerful secretion: Meat extractives such as are contained in soups, broths, and beef-tea. The secretion begins in thirteen minutes. Bickel found that in human beings alcoholic and carbonated fluids, spices, mustard, pepper, salt, cloves, also produced an abundant secretion. Craven Moore and Allanson found that tea was a stimulant to secretion, and coffee still more so in some individuals, though variable in its action. A cigar after meals stimulates secretion in an habitual smoker.

2. Substances producing a slight secretion : Milk, gelatine, water.

3. Substances producing no secretion: Egg-white, proteose, peptone, starch, sugar, salts of meat.

4. Substances inhibiting secretion: Fats and sodium bicarbonate.

In fact, secretion occurs in two stages, the first

depending on the stimulation of the sense of taste while the food is yet in the mouth, the second occurring when absorption has begun. The mechanism of this second secretion has been shown by Edkins to depend on a chemical factor, which explains the occurrence of digestion after division of the vagi. The pyloric glands differ widely in structure from the glands in the fundus of the stomach. Though the latter are simple tubular glands, they are composed of highly differentiated cells, the granular chief cells secreting the pepsin and rennin, the ovoid parietal cells forming the hydrochloric acid. Passing to the pylorus, we find a marked change in the plan of the glands, which have become wide-mouthed and branched; the lining cells are neither granular nor ovoid, but closely resemble those covering the surface of the stomach.

No theory of gastric secretion can be satisfactory that does not account for these striking differences of structure. It is the merit of Edkins' work that it at once explains the structural difference and the method of secretion in the absence of nervous impulses. He found that an extract of pyloric mucous membrane injected into the circulation of a fasting animal would cause the secretion of a juice containing both hydrochloric acid and pepsin. A similar extract of fundus glands produced no effect. Pyloric glands, therefore, produce a chemical stimulant or hormone to the continued secretion of gastric juice by the fundus glands, which is termed *gastric secretin*.

He tested the efficacy of certain substances in

evoking this stimulant in the pyloric glands. Of the various meat-extracts tried, Herzen's was the most marked and consistent in its effect, the percentage of acid being from 0·05 to 0·16 per cent. After meat-extracts came dextrose and then dextrin. Hydrochloric acid itself had very little effect.

He then divided the stomach into two portions by a tampon, and was able to prove that all the active juice was formed in the fundus, while the function of the pyloric portion was absorptive.

It follows that, as the food passes over into the pyloric portion, it can be sent on into the duodenum, if it be already sufficiently digested, but otherwise it is kept in contact with the pyloric glands, where it evokes renewed secretion from the fundus glands to complete its digestion.

And, indeed, if the appetite and sense of taste were the only stimulants to secretion, how would digestion be completed when the former was assuaged and the latter no longer exercised? Many animals, their hunger being satisfied, soon fall asleep. We see now that the secretion, started by nervous impulses, is continued by chemical stimuli, which will act as long as there is food in the stomach.

Movements of the Stomach.—This is a subject on which we have acquired a very large amount of information in recent years through the agency of the X rays. The anatomical conception of the position of the stomach has changed. Observations in the recumbent posture at operations and in the dissecting-

room where the stomach is unhardened, gave an erroneous impression. The œsophagus enters a little below the highest point, the part above the œsophageal opening being always occupied by a certain amount of gas. Then comes the body of the stomach, mainly vertical, and separated from the pyloric portion by the incisura angularis. The greater curvature reaches $2\frac{1}{2}$ inches below the umbilicus. As shown by Hertz, there is a great difference between the appearance of the stomach with the X rays and its position as determined by any method of percussion.

The amount of bismuth which is given for the purpose of taking X-ray photographs has been steadily increased up to 4 to 6 ounces of the carbonate or the oxy-chloride of bismuth. These do not produce toxic effects, although the subnitrate may. Barium sulphate has also been used, as it is cheaper, but it gives a less definite shadow. Either is given with ground rice, gruel, or bread and milk. In my opinion, Jordan's method is the simplest. He gives it suspended in water, with some lactose. It is, of course, necessary, before examining a patient in this way, that he should not have bismuth as a medicine for two or three days beforehand, otherwise the outline of the shadow will be obscured. It is important that in all cases the stomach should be examined both in the erect and in the recumbent postures. Omission of this precaution has led to some very erroneous conclusions. In the recumbent posture the stomach normally tends to adopt an hour-glass shape, from the

weight of the bismuth on either side of the vertebral column. In answer to the objection that the weight of the bismuth will distort the position of the stomach, it may be urged that this does not interfere with comparisons between the healthy and diseased organ. The food is seen to pass rapidly, and without the aid of peristaltic waves, to the pyloric portion. Here active waves are soon seen sweeping towards the sphincter about three times a minute, gaining force as they go. The absence of peristaltic waves at the cardiac end enables salivary digestion of carbohydrate to continue while gastric digestion is proceeding at the pyloric end. This affords a *rationale* for the custom of taking carbohydrate at the end of a meal. As the stomach empties it is pulled up until the pyloric orifice becomes the lowest part, which assists the completion of the process.

Cannon found that if carbohydrate be taken at the beginning of a meal it soon passes into the duodenum, but if protein is taken first the onward passage is delayed. This is because the acid of the gastric juice does not become fixed by carbohydrate, but, remaining free, is able to influence the sphincter; protein, on the other hand, fixes the acid, so that until digestion has proceeded far enough to set the acid free again the pylorus remains closed.

This is an adaptation to the fact that carbohydrate cannot be digested by gastric juice, so that as soon as acidity has put an end to salivary digestion no useful purpose is served by its retention in the stomach.

Whereas acid on the gastric side of the pylorus tends to open the sphincter, as soon as it reaches the duodenum it leads to closure of the orifice. This, as Cannon points out, is in accordance with the general law of peristalsis, that dilatation occurs below and contraction above the place of stimulation. Long after the fundus has returned to its fasting condition, the pyloric portion contains food, and shows those vigorous waves of contraction which form the 'gastric mill.' The semi-digested food is thus kept in close contact with the glands in which the stimulant to gastric secretion is elaborated, and thereby provides for its own digestion. It is probable that the much greater frequency of lesions at the pyloric as compared with the cardiac end is due to injuries incidental to its greater activity.

Practical Deductions.

The nervous factor in gastric digestion affords a scientific explanation of the old adage, 'Hunger is the best sauce.' Indeed, as we have seen, it is a sauce which will increase the rate of digestion fivefold. This must lead us to attach great importance to the personal equation in dieting a patient. Too rigid a dietary, albeit compiled on an admirable chemical basis, may prove distasteful and upset the appetite, thereby preventing all the good that might be expected. Nevertheless, in neurotic patients the very rigidity may cause interest, and thus excite the appe-

tite. I once saw an example of this in a typical neurasthenic. He complained that his food ' did him no good,' and he lost flesh until, becoming alarmed, he underwent a ' cure ' in Germany. It depended on an exact analysis of all the excreta, on the result of which the menu for the next day was drawn up. This process, which would have been repulsive to the average man, excited his interest keenly, and he throve greatly. He is now firmly convinced of the unscientific character of English physicians. The personal equation is, I think, too often neglected. Thus, fat has an inhibitory effect on gastric secretion in any case; to force it on a child who loathes it may be good moral discipline, but it is certainly bad physiology.

Our dietetic restrictions and prescriptions are too much dictated by fashion. Except in cases where we must forbid something for a perfectly definite reason, our patient's likes and dislikes should be carefully considered; whereas it is our own likes and dislikes which reappear constantly in our dietetic schemes. Given a certain knowledge of the man, one can predict fairly accurately what he will recommend to any patient. The dyspeptic is often a diligent seeker after medical advice, and when he tries to harmonize the various dietetic gospels he has received, his opinion of our profession is not enhanced.

' There is to be observed a sort of fashion running through these restrictions,' says Sir William Roberts, ' yet I know not on whose authority they repose. I do not think it is any medical authority. . . . They

are, for the most part, quite unmeaning; they stand on no ground of science or experience, and are gratuitously punitive to our patients. . . .

'There are cases in which a certain amount of coercion is salutary and even necessary. 'In neurotic and hysterical persons the stomach sometimes shares in the general instability, or it may even be the chief offender.'

Yet it is extraordinary that in many cases quite opposite methods of restriction should both be successful. A patient goes to one physician, whose opinion is that all purins are deadly poisons. He is put on a purin-free diet, and improves. Tiring of the restrictions, he seeks advice from another physician, whose opinion is that most ills are due to incomplete combustion of carbonaceous foods. These are now restricted, while he takes meat freely, and again he improves.

The explanation is that this is a type of patient who eats and drinks too much. Variety of diet stimulates his appetite, while the monotony entailed by abstention from so many pleasant things results in his eating less altogether.

In fact, there are really surprisingly few instances in which the addition of or abstention from some particular article of diet can be relied upon to produce a specific effect. Examples will be considered in their appropriate places.

The late Sir Andrew Clark was accustomed to forbid his dyspeptic patients to take soup, on the grounds

that, by diluting the gastric juice, it prevented digestion from proceeding. The advice was good in many cases, though the explanation was unphysiological. At this stage the gastric juice has not been secreted, and therefore cannot be diluted. Moreover, of all the chemical excitants of gastric secretion, meat-extracts have proved the most efficacious. To a tired man the warm fluid, causing gastric vaso-dilatation, and containing a stimulant of the gastric juice, while not in itself taxing the digestive organs, is an excellent beginning to a meal. It is important to note that meat-extracts mainly affect the production of hydrochloric acid, and cause little secretion of pepsin. In hyperchlorhydria, therefore, meat-soups are distinctly contra-indicated. while to dyspeptics with inadequate gastric secretion they are beneficial.

This explains the discrepancy between the results of analysis of meat-extracts and the popular estimate of their value. Their nutritional worth, so far from being accurately represented by pictorial advertisements, is stated to be equivalent to that of a teaspoonful of milk in a tumblerful of water. Yet as stimulants of gastric juice they have a decided place, and a patient may be able by their aid to tolerate a restricted and uninteresting dietary. But we must remember that we are not giving food; we are only preparing the way for food.

The tax which vegetable protein imposes upon the pepsin as compared with animal protein should not be forgotten in the construction of a dietary. Herein

lies the advantage of lightly cooked minced meat; it requires little pepsin, it does not easily ferment, and it does not leave a large indigestible residue. It is for this reason that it has proved useful in dilatation of the stomach. Surely it is a fallacy to administer so much starchy food in dyspepsia as is frequently done, when we consider its liability to ferment and the quantity of juice required for its digestion. A preparation that looks like milk does not necessarily become digested like milk! Harry Campbell has protested strongly against starchy food in the form of pap. It has to be swallowed at once, without any chance of salivary digestion, while in the solid form, requiring a good deal of mastication, it excites enough secretion of saliva to initiate its conversion into sugar. For this reason toast, biscuit, and rusk can often be digested when new bread or mashed potatoes cannot.

In many respects the physiologist's discoveries have been anticipated by the chef. We see the advantage of beginning a meal with soup to excite secretion, and of finishing with sweets, when the cardiac portion of the stomach will retain the food and permit continued digestion of the carbohydrates by the saliva. The postprandial cup of black coffee receives scientific sanction. The surroundings of a meal may have a physiological as well as an æsthetic value.

Pawlow's experiments also explain the different value attached to bitters by the clinician and the pharmacologist. It is true that, introduced directly

into the stomach or into the circulation, bitters are ineffective, but by exciting the nerves of taste and arousing the appetite while passing through the mouth they may be a distinct aid.

This has an important application in the treatment of patients on whom gastrostomy has been performed for stricture of the œsophagus. That the stricture is usually malignant is held to be sufficient explanation of the fact that such patients do not thrive. But they are also losing the powerful aid of 'appetite juice,' since the food no longer passes through the mouth. It is easy and rational to place sapid substances in the mouth to excite the sense of taste, while feeding through the gastrostomy wound is going on.

I know of one case in which the patient himself requested that he might take the food into his mouth and, after mastication, place it in his stomach through the gastrostomy wound. The request was granted, and the change seemed to benefit him. It was considered merely an unpleasant eccentricity on his part, whereas really he had anticipated Pawlow's discovery.

The Acid of the Gastric Juice.

Of all the constituents of the gastric juice, the hydrochloric acid is the most variable. Pepsin disappears in achylia gastrica, and is much diminished in gastric carcinoma, but otherwise alters but little in disease. How important the hydrochloric acid is can be realized by enumerating its functions.

1. It is essential to the activity of the pepsin, which is powerless in a neutral medium.

2. It is antiseptic.

3. It hydrolyzes starch to some extent, like any other mineral acid.

4. It regulates the pyloric sphincter.

5. It is a stimulant to the pancreatic secretion.

In gastric disorders it is often the hydrochloric acid that holds the key to the situation. If there were no hydrochloric acid, there would be no digestion in the stomach, while fermentation would proceed apace in the absence of the normal antiseptic; whereas, if there were excess of acid, the following results might be expected:

1. **Pain,** especially towards the end of digestion, when the stomach is getting empty. The pain, therefore, comes on sooner after a light meal, such as afternoon tea, than after a heavy meal. Thus, after evening dinner there may be freedom from pain till the middle of the night. The taking of food temporarily relieves the pain. This characteristic symptom of hyperchlorhydria has been called 'hunger pain' by Moynihan, who regards it as pathognomonic of duodenal ulcer. This pain is not the direct effect of hyperacidity, for Hertz has introduced stronger acids than are ever found in hyperchlorhydria without evoking it. It is probably due to—

2. **Pyloric Spasm,** excited by each gush of highly acid chyme into the duodenum; and thus, though gastric digestion is proceeding, the onward progress of the

food is delayed. The existence of this spasm can be readily demonstrated by the X rays.

3. **Pyrosis.**—This term should be kept, as Sir William Roberts advised, to a paroxysm of gastric cramp, accompanied by a sudden gush of saliva into the mouth. It is an attempt on the part of the body to neutralize the excessive acidity of the gastric juice by the alkaline saliva, but, like so many pathological attempts at repair, it overshoots the mark; for it is impossible for such a quantity of saliva to be swallowed.

4. **Appetite for Indigestible Things.**—The patient feels more comfortable when the gastric juice is given plenty to do, and therefore he often eats largely. There may be a positive craving for fat, which is comprehensible in view of its inhibitory effect on gastric secretion.

The principal conditions under which the acid of the gastric juice is deficient or absent are—

1. Chronic gastritis.

(*a*) Simple atonic, in which only the hydrochloric acid is reduced.

(*b*) Mucous, in which the acid is reduced, while the mucus is considerably increased.

(*c*) Atrophic (achylia gastrica), in which hydrochloric acid, pepsin, and rennin are all absent. This may also occur in pernicious anæmia.

(*d*) The gastritis of cirrhosis of the liver.

(*e*) The gastritis of congenital hypertrophic stenosis of the pylorus in infants.

2. Malignant disease.

The absence of hydrochloric acid from the gastric juice in malignant disease of the stomach is usual, but not invariable. Various explanations have been given for its disappearance.

(i.) Reissner found that, although there was loss of free hydrochloric acid in the gastric juice, the total chlorides were not decreased. This points to the neutralization by alkaline fluid secreted by the surface of a new growth. Graham's observations on the increased ratio of mineral chlorides to active hydrochloric acid confirm this.

(ii.) B. Moore and his colleagues maintain that there is a low secretion of free hydrochloric acid when malignant disease is present anywhere in the body, and not simply in the stomach, due to a diminution of hydrogen ions in the blood. While it seems clear that if metabolism be sufficiently depressed the output of acid is decidedly affected, it is too much to claim that malignant disease is peculiar in this respect. While hydrochloric acid may be absent in any cachectic condition, the active acid is not necessarily diminished in early or uncomplicated carcinoma of organs other than the stomach. Copeman and Hake found that in mice with carcinoma of other organs than the stomach there was no reduction in the active hydrochloric acid, but even a slight increase. And, as Willcox points out, it is absurd to draw a distinction between free HCl and HCl combined with protein.

(iii.) Another factor that seems to me to have been overlooked is the loss of gastric secretin, which is

a powerful stimulant to the secretion of the acid. The pyloric region is the one most frequently affected by cancer, and though hydrochloric acid is not formed there, destruction of the pyloric glands involves the loss of the chemical factor in gastric secretion. This would explain the cases where the total secretion of chlorides is low.

With all these influences—neutralization, depressed metabolism, and loss of the chemical stimulant—at work, the absence of free hydrochloric acid is not surprising.

The principal conditions under which the acid of the gastric juice is increased are—

1. 'Sthenic' dyspepsia, or the so-called acid dyspepsia of otherwise healthy persons.
2. Peptic ulcer, gastric or duodenal.
3. Chlorosis.
4. Cholelithiasis.
5. Chronic appendicitis.
6. Colitis.

Craven Moore suggests the term 'reflex dyspepsia' for hyperchlorhydria, which has the advantage of emphasizing the method of its production. It implies the existence of a lesion or an increased excitability of the reflex nervous mechanism, often both. If the lesion is severe, it can make itself felt, even though the nervous system is normal; but if the nervous system is unduly irritable, a very small lesion may produce marked symptoms. Thus we can understand why it occurs in the type of man it does, and why that

man 'who in the prime of manhood was a martyr to dyspepsia . . . in his later years, when his nerves are blunted . . . eats and drinks with the courage and success of a boy.' Another factor in the production of hyperchlorhydria which I have noted is the stimulus of a change of diet, such as occurs during a Continental holiday.

I do not think we can go as far as Moynihan in asserting that all cases of hyperchlorhydria depend on an organic lesion, usually an ulcer; but the diagnosis of simple hyperchlorhydria, or 'sthenic dyspepsia,' ought not to be made until every effort has been made to exclude the other conditions in which hyperchlorhydria occurs. It will be noted that these are chiefly conditions lower down in the alimentary canal. Now, if the intestine be wounded experimentally, there is inhibition of movements for some distance above, and there may also be spasm of the pylorus lasting for several hours. In the same way a duodenal ulcer, gall-stones, old appendicitis, and colitis set up a protective spasm above. This is usually at the pylorus, preventing the escape of acid from the stomach, though it may be elsewhere, producing pain without hyperchlorhydria.

Much can be learned from a careful comparison of the symptoms of hyperchlorhydria and achlorhydria, and I have placed the most important points of contrast in parallel columns. For many of these I am indebted to the writings of Leonard Williams.

	Atonic Dyspepsia.	Reflex Dyspepsia.
Test meal	Diminished HCl	Increased HCl.
Type of patient	Weakly, nervous, or convalescent. Generally tea-drinkers	Strong, active, energetic. Seldom teetotallers.
Mental State	Depression	Irritability.
Appetite ..	Capricious or absent	Voracious, especially for indigestible things.
Pulse ..	Quick and feeble	Good volume.
Character of pain	Discomfort usually present, becoming acute pain soon after taking food	Pain relieved by taking food, returning as the stomach is getting empty.

It must be noted that the occurrence of ulceration in the stomach confuses the clinical picture, since, although associated with hyperchlorhydria, it may occur in weakly, anæmic girls, and the pain, far from being relieved by taking food, is rendered acute. The localized character of the pain and the superficial tenderness will be important guides.

There are many cases, however, in which simple considerations are not sufficient, and recourse must be had to other methods of examination, such as the test meal and the X rays. Even from the test meal it would not be possible to diagnose between duodenal ulcer and simple hyperchlorhydria, but in the examination of the fæces for occult blood we have a very important guide. This is a simple enough test, and it is also valuable in the diagnosis of malignant disease

of the alimentary tract, because by this method blood will be found in practically every specimen of the fæces. Small continuous losses of blood are typical of carcinoma of the alimentary tract. In simple ulcer intermittent and larger losses of blood are more likely to be met with. If a patient has never had melæna or bright blood in the stools, but gives on three separate occasions a positive result with the test for occult blood, that patient very probably has malignant disease of the alimentary tract.

The test is performed as follows:

Take a small portion of fæces in a test-tube, add about 5 c.c. of water and boil thoroughly to destroy any vegetable oxidases, which would give a positive result, even in the absence of blood. A little benzidene is now added to some glacial acetic acid until a saturated solution is prepared. Ten drops of this are mixed with about three drops of boiled fæcal extract, and then 20 drops of a 3 per cent. solution of hydrogen peroxide are added. If any blood is present in the fæces, a blue colour will appear in about two minutes. A pale green colour is not enough to constitute a positive reaction; it must be a real blue. This is one of the most useful additions to the chemical methods of examination of gastric diseases. But it is very important before employing this test that the patient should be put on a meat-free diet for three days, and that the bowels should be opened in between. A soap-and-water enema should not be used for this purpose, as soap tends to prevent the reaction. There is no objection to a simple water enema.

Principles of Treatment in Asthenic Dyspepsia (Achlorhydria).

It goes without saying that in all forms of gastric affections the condition of the teeth and gums calls for attention. Carious teeth and pyorrhœa mean that mastication cannot be duly performed, and that septic absorption is taking place. But they are specially injurious in achlorhydria, where the antiseptic action of the hydrochloric acid is lost. The improvement in gastritis after removal of this source of infection is often surprisingly rapid.

Bunge has directed some pertinent criticisms against the indiscriminate use of alkalies in fermentative dyspepsia. While it is quite true that an alkali, by neutralizing the acids of fermentation, will relieve the symptoms, it will also neutralize the hydrochloric acid of the gastric juice, without which pepsin is powerless. As this acid is also antiseptic, fermentation will proceed apace in its absence, while digestion is arrested.

Except as a palliative, the usefulness of alkalies in conditions associated with diminished hydrochloric acid is limited to their administration before meals.

Even then it is not obvious how alkalies act beneficially, though the fact is undoubted. It used to be stated that they stimulated the flow of gastric juice, but Pawlow found that they inhibited the flow of both gastric and pancreatic juices. He believes that they insure physiological rest to a stomach which is in a condition of irritable weakness. Whether this ex-

planation be correct or not, the solvent action of alkalies on mucin must surely be a help to a stomach hampered by catarrhal exudation, enabling digestion to start with a clean slate.

While too much reliance has perhaps been placed on alkalies, certainly the use of acids has been somewhat neglected. We know that not only is the hydrochloric acid essential to the activity of pepsin and to the secretion of pancreatic juice, but that it is a valuable antiseptic, and helps the hydrolysis of the fermentable carbohydrates. We know also that its secretion fails in gastritis long before the pepsin disappears. Yet we still see dyspeptics sprinkling pepsin powders over their food while spurning the aid of hydrochloric acid.

The combined use of alkalies before meals, followed after meals by a good dose of dilute hydrochloric or nitro-hydrochloric acid with nux vomica, has given me more satisfactory results than either separately. And we should not be niggardly; for even the full pharmacopœial dose of 20 minims would only confer an acidity of 0·02 per cent. on a pint of fluid. Acidol (betain chloride) has the advantage of gradually giving off hydrochloric acid in aqueous solutions, and is more effective than the simple acid. It is quite stable in the dry state, and is readily soluble in water. Pastilles containing $7\frac{1}{2}$ and 15 grains are put up, and are equivalent to about 5 and 8 minims of hydrochloric acid respectively. They should be given freshly dissolved, and not swallowed in the solid form.

Patients usually tolerate the acid in this form without difficulty.

But cannot we induce the glands to form the acid for themselves? Remembering that interaction between phosphates and chlorides is the probable source of the acid, it might be thought that by increasing the phosphates of the blood more chloride would be set free as hydrochloric acid. But I have not had any success with this plan; the acidity of the gastric juice did not rise. The use of meat-extracts of various kinds has given me better results, and I believe they are valuable excitants of acid secretion.

In order to obtain appetite juice the idiosyncrasies of the patient must be studied. The condition is commonest in women, who are notoriously indifferent to the pleasures of the table, but whose æsthetic sense is responsive to pleasant surroundings and dainty service.

I have often allowed some food for which the patient had a special liking, even though it may have a bad reputation in dyspepsia. And the result seems to have justified this course. Articles which obviously disagree will naturally be prohibited, and it will usually be found that fats or meat with much fat in the fibre cannot be tolerated, because of their inhibitory effect on gastric secretion. As already explained, carbohydrates in the form of pap should be avoided.

Pawlow showed that he could retard the digestion of protein in dogs by mixing it with starch. And Cannon's observations suggest another important

reason against this procedure if gastric secretion be inadequate. When carbohydrates are given with protein they are retained in the stomach, and can ferment. But given by themselves they pass on more rapidly into the sphere of influence of the pancreas, where they are digested by the amylopsin. Therefore it is advisable not to give carbohydrate and protein together, but to give them as separate meals. Protein can often be tolerated as lightly-cooked minced meat.

Both in this and in the opposite condition of hyperchlorhydria it will, of course, be necessary to see that the bowels are freely opened. Small divided doses of calomel, followed by a saline purge, form an important preliminary to the treatment.

The golden rules, then, which I believe should guide the treatment of atonic dyspepsia are—

1. Satisfy yourself that the case is one with diminished secretion of hydrochloric acid ; in other words, make a correct diagnosis.

2. Encourage the secretion of ' appetite juice ' by careful consideration of the patient's idiosyncrasies.

3. Encourage the chemical stimulation of gastric juice by a small amount of meat-extracts or beef-tea at the beginning of a meal.

4. Never give carbohydrate in the form of pap, but in a form requiring mastication, and only give very small amounts with any protein meal.

5. Avoid fats.

6. Give acidol after food, and give alkalies with bitters only before meals when catarrhal signs are present.

7. Attend to the teeth and bowels.

8. Look for early signs of dilatation and treat it by lavage.

Principles of Treatment in Reflex Dyspepsia (Hyperchlorhydria).

The cause of the hyperchlorhydria must be sought for and treated. The administration of alkalis after meals is a rational procedure for the relief of symptoms, and no doubt the success of this treatment, indiscriminately employed as it often is, is due to the large proportion of hyperchlorhydrics among dyspeptics. The best alkali for the purpose will be one that does not distend the stomach by the evolution of carbonic acid gas on neutralization, and is insoluble, thus having a slow, continued action. Accordingly, I prescribe a drachm of liq. bismuthi hydratis (Parke Davis), which is equivalent to 10 grains of the carbonate, with 10 grains of heavy magnesia. The combination has the advantage that, while bismuth is constipating, magnesia is relaxing. Equal quantities of the two drugs tend to be too relaxing, so probably more bismuth may have to be added. Up to 2 drachms of the hydrated bismuth and 20 grains of the magnesia may be given with dilute hydrocyanic acid and chloroform water. I generally prescribe the two drugs in separate bottles, telling the patient to regulate the dose of each according as he is constipated or relaxed. The bismuth lozenge of the British Pharmacopœia, as

recommended by Sir W. Roberts, or the more elegant preparation called 'antacidol,' is often effective. They should be sucked slowly, thus providing for the swallowing of much alkaline saliva as well as the alkaline drugs. Their portability is another factor in their usefulness to sufferers, who are often of an active temperament. It might be expected that belladonna would have a good effect, because it is a powerful inhibitor of secretions; but, personally, I have found it disappointing. Craven Moore advises the use of ammonium bromide at the beginning of treatment to depress the excitability of the nervous reflex. Kaufmann believes that lack of the gastric mucus, which is normally a protection to the stomach, is a factor in producing pain. It is probable that any success attending the empirical use of silver nitrate is due to the gastric catarrh that it induces. He advises lavage with silver nitrate solution, 1 in 5,000, up to 1 in 1,000, for this purpose, and the method has met with some success. The risk of inducing argyrism must be borne in mind.

Olive-oil or almond-oil before meals may help, by reason of the inhibitory influence of fats on gastric secretion. Starting with a teaspoonful, the dose may be increased up to 1 ounce.

As to diet, I have followed the plan suggested by Walter Broadbent some years ago, based upon Pawlow's work, and that is to give the food in a form which will not excite more secretion of gastric juice than can be helped. There are five stages in the diet. I give

the patient a paper with these stages written down, and I explain that if he is getting better, he can pass from 1 to 5, and that if he is not so well he should work in the opposite direction. In the first stage, which is seldom required except when there is ulceration, he is only allowed milk and cream. In the second, bread and milk and soft milk puddings, such as cornflour. Thirdly, bread-and-butter and eggs. Broadbent says—although I have not found it so in all cases—that they are tolerated best in the form of buttered eggs, the butter still further diminishing the secretion of the gastric juice, while the large amount of protein in the egg will tend to fix the hydrochloric acid. Fourthly, fish and vegetables, and lastly meat; while we entirely forbid the use of meat-extracts of all kinds, because these stimulate the flow of gastric juice without giving anything for it to act upon. Such a scheme is useful in the treatment of hyperchlorhydria, enabling the intelligent patient to modify his diet according to the condition of his malady.

Physiological Principles in the Treatment of Gastric Ulcer.

During a period of eight years 428 cases were admitted to the medical wards of St. Bartholomew's Hospital as gastric ulcer, 366 being females and 62 males. Yet in the post-mortem room during the same period gastric ulcer was found in 20 females and 22 males. It is a very striking fact that, while the

mortality was almost exactly equal, there should have been so many more cases of hæmatemesis in young females, and one which lends some support to Hale White's contention that this symptom in young women is by no means always due to ulceration, but more often to a general oozing from the mucous membrane, for which he suggests the name of 'gastrostaxis.' It has happened that some of these cases have been operated on for the hæmorrhage, and that no sign of ulceration has been found. Some of these early cases have had very little gastric pain, and are usually quite amenable to treatment. The ones with a definite history of gastric pain are less amenable to treatment and more liable to relapse; these are probably cases of true ulceration. If it becomes established that profuse hæmatemesis may occur without ulceration, we shall probably have to modify our views as to the success of medical treatment in gastric ulcer, and to recognize that relapse is frequent.

The orthodox treatment for hæmatemesis is to secure physiological rest for the stomach. After an initial injection of morphia, and a dose of 30 minims of adrenalin chloride solution in $\frac{1}{2}$ ounce of water by the mouth, rectal feeding is started about twenty-four hours after the hæmorrhage.

Rectal Feeding.—Although rectal feeding has been practised since the time of Galen, its efficacy has not been established beyond cavil. At the outset its limitations must be recognized. It is quite impossible to nourish the body by means of suppositories, which

in all probability cannot be absorbed at all. In some cases the rectum and colon have been found loaded with them at the post-mortem examination. As the large intestine is the principal place for the absorption of water, it is essential, if we are to have any success with rectal feeding, to take advantage of this fact by giving the nourishment in a fluid form. But even in this form its efficacy is open to doubt. The power of the large intestine to digest foodstuffs is very slight. Whether undigested albumen can be absorbed at all is merely of theoretical interest; it is certainly absorbed in much too small an amount to make it of any value if thus administered. Erepsin is the only proteolytic ferment secreted by the intestine which can break down proteoses and peptones into simpler bodies prior to absorption; it can only act on caseinogen and fibrin among the native proteins. As erepsin ordinarily acts after pancreatic juice, we should naturally predigest the proteins by liquor pancreaticus before administering it *per rectum;* this has a further advantage over merely peptonizing agents in digesting carbohydrates and fats also. Even when the rectal feed is completely pancreatized, it is doubtful how far it can be absorbed. Though the large intestine absorbs water readily, food is normally absorbed as completely as it can be in the small intestine. The highly specialized epithelium over the villi is the main agent in this. It is a pure assumption to conclude that the widely different epithelium of the large intestine can act in a similar manner. Yet the administration of small

nutrient enemata is based on that assumption. It has been claimed that the larger enema will get through the ileo-cæcal valve, and be absorbed in the small intestine. Church noted in a case of duodenal fistula that some of a soap and water enema reappeared through the opening. Charcoal particles administered in an enema have been found in the stomach. But we cannot rely on this regurgitation as a regular event. Boyd has looked carefully for it by the charcoal method, without success. Moreover, only large enemata can be expected to reach as high, and the larger the enema the more difficult it is to retain.

Turning from these *a priori* considerations to actual results obtained, I will first summarize some of the previous observations, and then my own experiments.

Absorption of Proteins. — Some observers have thought that quite large amounts of proteins were absorbed. But there was an important source of fallacy in the method employed; it was assumed that the nitrogen which could not be recovered from the bowel was assimilated. But it is notoriously difficult to recover everything from the bowel by washing it out. Even when daily irrgations have been given with scrupulous care, there may be days afterwards an evacuation of a large amount of highly putrid material. And in any case, some of the protein which disappears may have been reduced by putrefactive changes into a form in which it has no nutritional value.

Even assuming that all the nitrogen which could not be recovered had been assimilated, nitrogenous

equilibrium could not be obtained during rectal feeding, even in those who were accustomed to a diet poor in nitrogen (Boyd).

Laidlaw and Ryffel estimated the nitrogenous output in a case of rectal feeding during coma, and found that it was approximately equal to that obtained in the later stages of fasting—as, for instance, with the professional faster Succi, from the fifteenth to the twentieth day. The nutrient enemata in this case contained the white of nine eggs, 6 ounces of raw starch, and 24 ounces of peptonized milk in the day. It may be remarked that egg-white would not be readily absorbed, while it is doubtful if starch can be digested by the large intestine at all.

Absorption of Carbohydrates. — Normally, carbohydrates are absorbed by the bowel as dextrose, and of all the foodstuffs this appears to be the best utilized in rectal alimentation. Using recovery methods, different observers claimed that 67 to 100 per cent. was absorbed. It has been urged that here again bacterial decomposition accounts for much of the disappearance of the carbohydrate. Boyd found, however, that the *Bacillus coli* could only account for the disappearance of about 1 per cent., but does not state whether the lactic-acid-forming organisms could not be responsible for more than this. That dextrose is definitely absorbed from the bowel is, however, proved by the following facts: Reach found that the respiratory quotient was raised by rectal feeds of dextrose—a sure sign that they were being utilized—and acidosis

has been abolished by this procedure. Nothing abolishes acidosis so rapidly as assimilation of carbohydrates, just as nothing causes it to appear so quickly as deprivation of carbohydrates.

Absorption of Fats.—No emulsion, however fine, is absorbed in the absence of splitting ferment. This ferment is normally supplied by the pancreatic juice, and in its absence we have to depend upon bacterial decomposition. It is a simple matter to provide the ferment by liquor pancreaticus, but even then absorption may be very imperfect. In one of Edsall's and Miller's cases only 13·61 per cent. of the fat was absorbed. The fat in the yolk of egg is considered to be better absorbed than other forms of fat, but, personally, I do not employ eggs in rectal feeding, for they add to the nursing difficulties, already sufficiently great. If any of the egg is returned, it is very offensive.

In a patient with a fistula of the thoracic duct, Munk and Rosenstein only found 3·7 to 5·5 per cent. of the fat given *per rectum* could be recovered. I have carried out rather similar observations on a case of filarial chyluria under the care of Dr. Samuel West. On an ordinary diet the urine was quite milky, and he was placed on a fat-free diet to relieve the pain and occasional hæmaturia caused by the passage of large fatty masses. The urine then became merely opalescent, but even the addition of milk to his tea caused an obvious increase in the fat in the urine. After determining the amount of bodies soluble in ether and the saponification value of the urine on the fat-free

diet, he was given an enema of 120 c.c. of olive-oil and 80 c.c. of a 2 per cent. solution of Na_2CO_3, which had been pancreatized for an hour. On another occasion he was given a pint of pancreatized milk *per rectum*. It happened that the saponification value and the ether-soluble bodies were actually lower in amount on the days when these enemata were given. This indicates that no fat was absorbed from these enemata by the large bowel.

Absorption of Salt and Water.—It is agreed that salts and water are freely absorbed from the large intestine, and the advantages claimed for rectal feeding are probably due to these ingredients. It is well known that the body can stand deprivation of food for a considerable time if these are supplied. W. Pasteur advocated the administration of 10-ounce enemata of plain water at a temperature of 100° F. every four or six hours. He claimed that the results were at least as good as with the ordinary nutrient enemata, while it is far simpler and pleasanter for the patient. Sharkey has used $\frac{3}{4}$ pint of saline four times in each twenty-four hours, and has been equally impressed with the advantages of this method.

Nitrogenous Metabolism during Rectal Feeding.—My own observations have been chiefly directed to comparing the nitrogenous metabolism in patients on rectal salines and nutrient enemata. The nutrient enema which I have usually employed is composed of—

4 ounces of milk.	20 grains of bicarbonate of soda.
1 to 2 drachms of plasmon.	1 drachm of liquor pancreaticus.
1 to 2 drachms of dextrose.	5 minims of tinct. opii.

The liquor pancreaticus is allowed to act for twenty minutes at 37° C., the opium being added just before administration, with the object of increasing the tolerance of the bowel. The bicarbonate of soda is added to imitate the normal alkalinity of the pancreatic juice (1 per cent.). This enema is given every four hours, the rectum being washed out every night and morning. The total foodstuffs thus given in the twenty-four hours amount to—

Proteins	75 grammes.
Carbohydrates	75 ,,
Fats	27 ,,

This is clearly much less than the minimum required to keep the body in nitrogenous equilibrium, even supposing it were all absorbed, which is far from being the case, while its caloric value is only 866.

The larger enema—a pint of milk three times a day—has not yielded me very good results though recommended by some authorities, the patient usually failing to retain them after the first day or two. This would be equivalent to 68 grammes of each of the three foodstuffs, and its caloric value would be 1,188. I have no personal experience of the enema administered continuously drop by drop, but I have heard from those who have that it caused the patients so much discomfort that they were forced to abandon it. The enemata were administered in my cases by a soft rubber catheter attached to the barrel of a 4-ounce glass syringe, the contents being allowed to flow in slowly by gravitation.

When no nitrogenous food is taken there is a steady fall of nitrogen in the urine till the output reaches 5 grammes a day, and even lower. One of the first effects of giving nitrogenous food will be a rise in the nitrogenous output in the urine, as the greater part of the urea is exogenous—*i.e.*, comes from the food. The nitrogenous output in the urine will therefore be a more accurate criterion of the absorption of nitrogenous material from the bowel than the loss of nitrogen from the rectal washings, because it is evidence of actual assimilation. When rectal salines are given, there is a steady fall of urinary nitrogen. Starting with 10 grammes to 11 grammes the first day, it falls to about 5 grammes by the fifth day, and usually remains at that point, though in some of my cases it fell as low as 3 grammes, or even 2 grammes, a day. Acetone usually appears by the end of the first twenty-four hours, and diacetic acid within the next twenty-four hours. On comparing this with the cases where the standard enema was employed, hardly any difference was detected in the nitrogen output. There was a steady fall in the total nitrogen down to 5 grammes, and in one case as low as 4 grammes. The onset of acetonuria was, however, delayed as a rule, and it was usually less severe and of shorter duration. The great factor in the production of acetonuria is deprivation of carbohydrate, and as the enema contained both dextrose and lactose, the disappearance of acetonuria indicated that some of these were absorbed. In some cases acetonuria persisted throughout.

In one experiment salines were given till the nitrogen in the urine fell to 5 grammes. The standard enemata were then given for two days, but the nitrogen output was hardly affected at all. The same amount of food was given by the mouth, and the nitrogen output promptly rose.

Practical Deductions.—I think these results go to show that if any protein food is absorbed from ordinary nutrient enemata, the amount is so little as to make it hardly worth while to subject patients to so much discomfort for so small an advantage. A gain in weight has been claimed as evidence of their value, but this has been observed also on rectal salines. The addition of 5 per cent. of dextrose to the salines is probably an advantage, as enough of it may be absorbed at any rate to check acidosis.

When one begins to doubt the efficacy of rectal feeding, the inconveniences associated with it assume a greater degree of importance. As disadvantages must be mentioned—(1) The thirst, which should be relieved by giving a rectal saline as well; (2) the difficulty in keeping the patient in a cleanly condition; (3) the secretion of gastric juice which it causes. The most conclusive evidence that this occurs is afforded by the observation of Umber, who found in a patient with a gastrostomy wound that the injection of food *per rectum* was followed by the secretion of an acid gastric juice. It is hardly securing a condition of physiological rest to allow this juice to be poured over an ulcerated surface without having

any food on which to act. To neutralize this juice I was accustomed to give the patient bismuth lozenges to suck. This serves both to neutralize the acid and to form a protective covering to the ulcer. At the same time, by keeping the salivary glands active, it diminishes the chance of (4) parotitis, which is due to an ascending infection of the salivary ducts. I am quite sure that in this way it is much easier to keep the mouth clean. Incidentally, I should like to protest against the use of glycerine in a mouth-wash for this or, indeed, in any other condition. The desiccation which follows only aggravates the state of the mouth. Ice is also objectionable; though pleasant at the time, it aggravates thirst. Plain hot water, to which a little potassium permanganate has been added, is, in my opinion, much to be preferred. (5) Persistent vomiting is an occasional complication in rectal feeding. If this starts, it generally persists until mouth-feeding is resumed. Unfortunately, it is often regarded as a sign that the stomach cannot tolerate anything, which is not the case. I believe it is due to the acidosis consequent on starvation. (6) The pronounced subnutrition induced by rectal feeding is very unfavourable to the healing of an ulcer in patients who are already in a poor physical condition consequent on one or more hæmorrhages, and may lead to serious inanition. Self-digestion goes on more rapidly in fasting than in well-fed tissues, and this may lead to extension of the ulcer and recurrence of the hæmorrhage. It is useless to think of building up a patient

by this method to a condition of improved nutrition prior to operation, for, say, an impermeable œsophageal or pyloric obstruction. I have only once attempted this at the request of a surgical colleague, and I shall not repeat the attempt.

It seemed to me possible that better results might be obtained if, instead of merely peptonizing proteins, they were completely broken down into amino-acids, the form in which absorption normally occurs. Some preliminary experiments did not afford me much encouragement. Rendle Short and Bywaters, however, found that, by allowing pancreatic extract to act on milk for twenty-four hours, they could obtain decidedly more absorption. To each pint of milk they added an ounce of pure dextrose, and gave 5 ounces of this every four hours. I have used a Thermos flask as a convenient method of keeping up the pancreatic digestion for the required time. This plan is worthy of a trial in exceptional cases, and I have met with some success with it, but for the ordinary nutrient enema containing protein and fat there is, in my opinion, no place left to-day in therapeutics.

Immediate Feeding in Gastric Ulcer.

In 1901 Lenhartz protested strongly against the orthodox treatment for gastric ulcer. He urged that in patients who are already in a poor physical condition consequent on one or more hæmorrhages, and, indeed, often collapsed, the 'starvation treatment'

maintained their wretched anæmic state, and might produce a serious state of inanition, very unfavourable to the healing of an ulcer. On the other hand, if enough milk were given by the mouth to maintain the body-weight, it would overfill the stomach and stretch its walls, thus preventing contraction of the ulcer and tending to renewal of the bleeding.

He maintained that the correct principles were—

1. To promote healing by providing adequate nourishment.

2. To prevent distension of the stomach by limiting the size of the meals and the amount of fluids; and by the application of ice to the epigastrium.

3. To prevent the action of the excess of hydrochloric acid by combining it with food albumen and with bismuth.

These indications are best fulfilled, in his opinion, thus: Feeding by the mouth is started at once, concentrated foods rich in albumen being employed. Food is given at hourly intervals from 7 a.m. to 9 p.m., but complete rest is allowed at night. The patient is fed a teaspoonful at a time, and is not allowed to feed herself for a fortnight. She is kept in bed for a fortnight, and other medicinal measures, such as the administration of bismuth, can be employed as required.

Essentially the diet consists of iced fresh milk and raw eggs, the whole egg being beaten up and iced. Both milk and egg are prepared in a covered glass tumbler surrounded by ice. The feeding-spoon is also kept iced. Granulated sugar is added to the eggs on

the third day; later, raw scraped beef, boiled rice, and soaked rusk are also given. The table on p. 83 gives the quantities allowed in the original Lenhartz dietary; some modifications will be discussed later.

In English measures these quantities mean on the first six days that the patient is taking—

Day.	Eggs (Drachms per Hour).	Milk (Drachms per Hour).	Sugar (per Diem).
1	2	4	—
2	3	6	—
3	4	8	1 ounce to eggs
4	5	10	1 ,, ,,
5	6	12	1½ ,, ,,
6	7	14	2 ,, ,,

No attempt is made to provoke an action of the bowels during the first week at least, to avoid peristalsis, and allow absorption of outpoured blood in the intestines. Then, if necessary, a small glycerine enema or hot-water enema may be used.

The advantages claimed for this treatment are that recovery is more rapid, and that it does not deplete the patient, the food-supply being sufficient throughout. The sour regurgitation subsides, vomiting and bleeding stop more quickly, and relapse is less frequent, while pain ceases promptly, and morphia is never needed; it is possible to treat the anæmia earlier, and an increase in the body-weight may be manifest as early as the first week.

ORIGINAL LENHARTZ DIETARY.

Days	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Eggs	2	3	4	5	6	7	8	8	8	8	8	8	8	8
Sugar, with eggs (in grammes)	—	—	20	20	30	30	40	40	50	50	50	50	50	50
Milk (in cubic centimetres)	200	300	400	500	600	700	800	900	1,000	1,000	1,000	1,000	1,000	1,000
Raw scraped beef (in grammes)	—	—	—	—	—	35	70	70	70	70	70	70	70	70
Milk rice (in grammes)	—	—	—	—	—	—	100	100	200	200	300	300	300	300
Rusk (soaked), 1 piece=20 grammes	—	—	—	—	—	—	—	1	2	2	3	3	4	5
Raw ham (in grammes)	—	—	—	—	—	—	—	—	—	50	50	50	50	50
Butter (in grammes)	—	—	—	—	—	—	—	—	—	20	40	40	40	40
Represents in calories	280	420	637	777	956	1,135	1,588	1,721	2,138	2,478	2,941	2,941	3,007	3,073

One important modification I have found advisable to make. Cases in which active ulceration is present usually do not tolerate the raw meat as early as the sixth day, and I do not think it wise to make them try and do so. Pawlow showed that meat-extracts were active stimulants to the secretion of acid in the gastric juice, and our object in these cases is to avoid hyperchlorhydria, while fixing such acid as is present by combining it with protein. The nourishment in the 36 grammes of beef can be readily obtained in a less stimulating form by adding 2 drachms of a milk protein, such as plasmon or protene, to the diet.

Another minor modification of the original dietary in which I have followed Lambert is the substitution of cooked minced chicken for the raw ham, which, however suitable for German patients, is not grateful to English palates. I have also given rectal salines, if required, to relieve thirst. Lenhartz found that in the 100 cases treated before he introduced this method, recurrence took place in 20 per cent., but after introducing this treatment recurrence occurred in only 8 per cent. The method has been taken up on the Continent to a considerable extent and also in America, but up to a few years ago it had made very little headway in England. There seems to have been considerable prejudice against it. At last, however, people are beginning to realize that it is an important advance, and it is now rapidly becoming the orthodox method. I will give the results in my first thirty hospital cases, none of which have been treated during the last twelve

months, so as to give some chance of finding whether there was recurrence. But we know how difficult it is to do this in the case of hospital patients. There had been recent hæmorrhage in seventeen out of the thirty cases. In one case it is probable that the hæmorrhage was from cirrhosis of the liver, but I could not be certain as to the source, and I have included it. The treatment was quite satisfactory in twenty-two cases. The result was unsatisfactory in four, and there was recurrence of the hæmorrhage in four others. In one there was recurrence subsequently with nutrients, just as with Lenhartz treatment. In another the recurrence was very slight, amounting to the regurgitation of a drachm of blood. In a third case, with a history of sixteen years, recurrence had previously taken place on nutrients. Gastro-jejunostomy was performed, and the hæmorrhage recurred a few months after the performance of that operation. Finally, an ulcer surrounded by dense adhesions to the liver had to be excised, and the patient made a good recovery. In another case recurrence took place, and gastro-jejunostomy had to be performed for a chronic ulcer. Unfortunately, the patient died of peritonitis, the direct result of operation. As to the four which I have classified as unsatisfactory, apart from recurrent hæmorrhage, one discharged himself on the fourth day —a thing which is common enough in patients treated by nutrients. In one case there was mucous colitis also. With this complication the treatment of the gastric condition, which I believe to be secondary, is

often of no avail. Another case was that of a neurotic alcoholic lady, on whom I tried it simply because no other treatment of her gastric pain had done any good. In the fourth case, although there was great temporary relief, the X rays showed an hour-glass stomach, for which operation had to be performed. Here, too, there were dense adhesions, and a gastric fistula formed, with fatal results. Clearly the fatalities had nothing to do with the Lenhartz treatment; they were both in cases of long standing, and certainly would not have been avoided by rectal feeding.

On the whole, I have been most favourably impressed by the method, and I am supported by my house-physicians and the sisters in charge of the cases, who would much rather have to deal with a case treated on this plan than on the other, avoiding, as it does, the misery of starvation and all the discomforts of rectal feeding. The method is peculiarly suitable for the conditions of private practice. Nutrient enemata require time and skill in their preparation. We cannot expect them to be given properly except by a trained nurse, whose services cannot always be afforded. But in this method we have a simple, safe, and effective treatment, which is free from any disagreeable features.

The use of horse-serum has been advocated by Hort and others for gastric or duodenal ulcer. One of the many functions of serum is the restraint it exerts on the autolytic action of the tissue cells. As autolysis goes on more rapidly in fasting than in well-

fed tissues, there is a rational basis for the use of horse-serum in a disease for which most methods of treatment entail more or less starvation. The antipeptic action of serum depends chiefly on the serum-albumen it contains, and Hort has prepared a serum in which this constituent is specially increased in amount. It can be given in daily doses of 30 to 40 c.c., but it must be fresh and sterile, and should be given directly after food, when absorption is at its height. I have not been greatly impressed by the results, and when starvation methods are not used serum is hardly called for.

The later results of gastric ulcer are chiefly due to the mechanical difficulties produced by scar tissue, such as pyloric obstruction and hour-glass stomach. They may, therefore, be more conveniently considered in the next chapter.

APPENDIX TO CHAPTER II

Examination of the Gastric Contents.

That doubts are so often thrown on the value of a chemical examination of the gastric contents is due in many cases to the fact that defective methods have been employed. It is not sufficient to test qualitatively for free hydrochloric acid, and then take the total acidity as a measure of the physiologically active hydrochloric acid.

The test-meal I employ is $\frac{3}{4}$ pint of tea without milk

or sugar and a round of dry toast, which is quite satisfactory as an excitant of gastric secretion. The contents of the stomach are withdrawn one hour later. For this I always employ Senoran's bottle, which is simple and efficient, and overcomes any difficulty in starting the syphonage. The patient should be sitting up, with the head rather forward. The natural tendency is to throw the head back, but there is less difficulty if the head is tilted forwards. The tube is lubricated by being simply dipped into hot water and passed as quickly as possible, the patient being directed to swallow it, while the first finger of the left hand is used as a guide. The distance from the teeth to the stomach is generally $15\frac{3}{4}$ inches, which is just under 40 centimetres. The tube is passed till the 45-centimetre mark on it is level with the teeth. With the tube in position squeeze the bulb, and then, before releasing, put the thumb or finger over the little hole in the side of the bottle-neck. There is then an efficient suction action in the tube, and the contents of the stomach are speedily extracted into the bottle. If you do not withdraw enough, repeat the squeeze, taking care to remove the thumb until you let go of the bulb, or else air will be driven into the stomach, which is uncomfortable. The bottle is provided with a rubber band to close the hole, and a rubber stopper to make it portable.

The contents of the bottle are filtered and some of the residue examined microscopically. If starch digestion is very incomplete, it points to excess of acid,

which stops the ptyalin of the saliva too soon. If the contents are frothy, it suggests carcinoma. The presence of the long, non-motile Oppler-Boas bacillus is said to be specially diagnostic of gastric carcinoma. Really it means there is no free hydrochloric acid, which is commonest in carcinoma. It is a lactic-acid-producing organism, and, according to some, it is the same as the Bulgarian bacillus, of soured-milk fame. The presence of sarcinæ is believed to be a sign of dilatation of the stomach. No importance should be attached to the presence of yeast, which merely comes from the bread.

Gunzberg's is the most reliable qualitative test for detecting free hydrochloric acid. 'The best way of applying the test is to keep the phloroglucin and vanillin in bottles to the corks of which are attached little scoops which will measure about 4 grains of the former and 2 grains of the latter. These quantities are placed in a dry porcelain evaporating-dish with 1 c.c. of alcohol (pure methylated spirit does quite well), and then about 2 c.c. of the filtered gastric contents are added. The dish is heated on the water-bath till its contents are nearly dry. A brilliant scarlet-red colour indicates free HCl; a yellow colour is negative' (Willcox).

Total acidity is determined by titration with a decinormal alkali, using phenolphthaleïn as an indicator.

The amount of physiologically active hydrochloric acid is the most important point, and this can best be determined by Willcox's method. The principle of it

is as follows: In the gastric contents hydrochloric acid may exist in three forms—

1. Free HCl	Physiologically active.
2. Combined HCl:	
(*a*) With proteins and nitrogenous organic bases ..	
(*b*) With inorganic bases, as sodium chloride.	

The presence of free HCl is not of more importance than that of the combined acid. The latter, which is combined with protein and nitrogenous organic bases, is acid that was free a short time before, but has now begun its duties in the process of digestion; it is, therefore, of equal importance with free HCl.

Now, if we estimate the total chlorides in a sample of gastric juice, and in another estimate the chlorides present after charring—*i.e.*, the inorganic chlorides—the difference between these two results gives the amount of physiologically active HCl.

The estimation is carried out as follows, but I am accustomed to use half the quantities given here: 'Two equal volumes of the filtered gastric contents (20 c.c.) are taken.

'(*a*) One portion is diluted with about 40 c.c. of distilled water, 10 c.c. pure nitric acid added, and about 5 c.c. of solution of iron alum. A measured excess (30 c.c.) of decinormal silver nitrate solution is added. Decinormal ammonium sulphocyanide solution is run in from a burette until a permanent reddish-brown tint just results. The difference between the quantity of silver nitrate solution added and the ammonium sulphocyanide solution used gives the amount of total chlorides present as decinormal hydrochloric acid.

'(*b*) The other portion of the gastric contents (20 c.c.) is placed in a platinum evaporating-basin, and evaporated to dryness on a water-bath; the solid residue is heated for about an hour on the water-bath, and the dish is then placed on a piece of wire gauze and heated with a small Bunsen flame, the flame not coming into actual contact with the basin. The heating is continued for about ten minutes until the residue is well charred. The dish is cooled, about 60 c.c. of water and the pure nitric acid are added, the contents being well stirred with a glass rod. The titration is performed exactly as in (*a*), and the quantity of chlorides present is given in terms of decinormal hydrochloric acid. The difference between the chlorides present in (*a*) and (*b*) expresses with great accuracy the amount of the physiologically active HCl.'

[For a fuller account of methods, see Willcox, Transactions of the Pathological Society, vol. lvi., p. 250; and Harley and Goodbody, 'Chemical Investigation of Gastric and Intestinal Diseases' (Arnold).]

The following figures illustrate the results obtained in some typical cases:

	Gunzberg's test for free HCl.	Physiologically active HCl.	Mineral Chlorides.	Total Chlorides.	Ratio of Active to Mineral.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Normal	+	·2	·1	·3	$\frac{200}{100}$
Cancer	—	·01	·17	·18	$\frac{6}{100}$
	—	·075	·219	·294	$\frac{34}{150}$
Chronic gastritis ..	+	·14	·12	·36	$\frac{117}{100}$
Simple hyperchlorhydria	+	·34	·076	·416	$\frac{447}{100}$
Duodenal ulcer	+	·301	·1	·456	$\frac{300}{100}$

CHAPTER III

MECHANICAL FACTORS IN DIGESTION AND INDIGESTION

It should hardly be necessary to insist on the cardinal importance of the teeth in the due performance of mastication, without which the food cannot be insalivated. It may appear paradoxical to assert that the inevitable tendency to swallow soft carbohydrates is a more serious consequence of defective teeth than the bolting of meat. Yet I believe this to be the case, for, as explained already, carbohydrates are not then digested in the stomach, where they are apt to ferment and produce flatulence.

Deglutition.—The act of swallowing consists of three stages, the first of which is voluntary, the food bolus being thrust between the pillars of the fauces by the tongue. After this all voluntary control over the movements of the alimentary canal is lost until the rectum is reached. The contact of the food against a specially sensitive spot on the back wall of the pharynx starts the subsequent stages. We have only to swallow several times in rapid succession until no more saliva is present in the mouth to realize how impossible the act becomes in the absence of a peripheral stimulus. The second

stage is a rapid reflex, rapidity being necessary, as the pharynx is common both to respiration and alimentation. The upper and lower parts of the respiratory tract are shut off by the elevation of the soft palate, by pulling up of the larynx under shelter of the epiglottis, and the approximation of the vocal cords. The importance of these protective movements is seen in the regurgitation of fluids through the nose when the soft palate is paralyzed by diphtheritic neuritis, and in the dysphagia which results from the destructive tuberculous ulceration of the epiglottis.

The constrictors of the pharynx are now drawn over the food bolus, which is thus forced into the œsophagus. Here the third stage of deglutition begins, a slow peristalsis which depends on the vagus as far as the striped muscle is concerned, and on local nervous mechanisms as far as the plain muscle is concerned. In the swallowing of liquids, however, there is no need for peristaltic waves, the œsophagus remaining dilated and passive. During swallowing a pressure develops in the closed mouth equal to 20 centimetres of water, while immediately after the stomach relaxes, so that the intragastric pressure falls almost to zero, which is sufficient to direct the stream of fluid into the stomach. Hence, when corrosive acids have been swallowed, the lesions are produced in a patchy manner, which would not occur if the fluid were forced down by a peristaltic wave. The passage of fluid down to the stomach takes four to eight seconds, half of which time is occupied in passing through the cardiac sphincter.

Solids require the aid of peristalsis, and take eight to eighteen seconds if well lubricated, but a dry bolus may remain above the cardia for many minutes (Hertz). The peristaltic wave can act against the force of gravity, for swallowing can be accomplished in the inverted position, though more slowly.

The different conditions obtaining in the swallowing of liquids and solids explain some of the symptoms in malignant stricture of the œsophagus. At the necropsy it may appear as if there could have been no difficulty in swallowing food or in the passage of a bougie, but, of course, much of the obstruction is due to spasm. It is common for the dysphagia to begin suddenly during a hearty meal. A spasm has been evoked and will recur on each attempt at deglutition. I have seen the same thing occur in congenital œsophageal stricture. As the act of swallowing liquids excites no spasm but rather an inhibition of peristalsis, it is easily performed long after all solids are unable to pass. It is important to note that a spasm may result from a growth lower down the œsophagus or at the cardiac orifice, which, like the gastric spasm to be referred to later, is presumably protective in nature.

Just as acid in the duodenum keeps the pyloric sphincter closed, so acid in the stomach keeps the cardiac sphincter closed. This is a great advantage, for the gastric contents are nauseating in odour and highly disagreeable to the taste. But when the intragastric pressure rises above 25 centimetres of water eructation or regurgitation occurs, to be followed

promptly by œsophageal peristalsis forcing back any food into the stomach again. In œsophagismus, the spasmodic contraction of the œsophagus sometimes met with in hysterical women, there is probably an exaggeration of the ring of contraction which normally moves up and down the lower part of the œsophagus. The accentuation of the symptoms by acid dyspepsia is similarly explained as an exaggeration of the ordinary effect of acid in keeping the cardiac sphincter closed. Conversely, Kast has suggested that the disagreeable taste in the mouth and the furred tongue of gastric disturbances is due to the adhesion to its rough surface of partly digested pieces of food, leucocytes, and epithelial cells, which have come back from the stomach. Such symptoms are commonest in the fermentative dyspepsia associated with deficiency of HCl, which is precisely the condition for a relaxed cardia.

The Stomach.

The movements of the normal stomach have been described in the previous chapter.

Spasmodic Hour-Glass Contraction.—Much controversy has centred round the question of the existence of a ' middle sphincter ' in the stomach. We now know that while under abnormal stimuli the circular muscle at the beginning of the pyloric vestibule is capable of powerfully contracting and dividing the gastric lumen, this is not normal. The condition is liable to be mistaken for an organic hour-glass con-

traction. Jellasse, in 1906, suggested, and it is generally agreed, that it can arise from spasm. It is most usually due to the presence of an ulcer, which is generally situated on the lesser curvature, and may be quite small. But it may occur in other conditions. Thus, I had a case associated with old appendicitis, in which the spasm could be seen gradually to relax under anæsthesia. I believe that the symptoms in so-called 'appendix dyspepsia' are in part, at any rate, due to such reflex spasm. The spasm can sometimes be made to disappear by abdominal massage, by vigorous voluntary contractions of the abdominal muscles, and less frequently by the injection of $\frac{1}{100}$ grain of atropine. The contracted area varies in degree; there is no sagging or peristaltic wave in the proximal half of the stomach. These three points serve to distinguish spasmodic from organic constriction. It must be remembered, however, that a partial organic hour-glass constriction due to an ulcer which is still active may be rendered complete by the supervention of spasm, so that stenosis, thought to be severe from the X-ray examination, may be found to be comparatively slight at the operation.

Hertz describes two other conditions as 'functional' hour-glass stomach. One is due to the combination of severe atony with gastroptosis, in which the passage between the more fixed fundus and the dependant part of the stomach becomes much narrowed by the dropping of the latter. But this appearance completely vanishes in the recumbent posture, and he

therefore terms it 'orthostatic.' To the other form, the term 'functional' is hardly applicable. It is due to an ulcer on the lesser curvature which has become adherent to the left lobe of the liver. When the patient stands up, the rest of the stomach tends to assume a vertical position, but the adherent part being fixed, a line of tension is produced diagonally across the stomach, dividing it into two parts. But here, again, the constriction disappears on lying down. Incidentally I may say that this form is resistent to medical treatment, and offers considerable difficulties to surgery. Strictly speaking, it should be classed among the perigastric adhesions.

True Hour-Glass Stomach.—Extended use of X rays has shown that this condition is a commoner sequel of gastric ulcer than was supposed. Apart from the characteristic skiagram, the chief signs are those described by Moynihan. When the stomach is washed out, part of the fluid is lost, and conversely there may be a sudden reappearance of stomach contents after lavage. When the stomach has apparently been emptied, a succussion splash may still be elicited by palpation of the pyloric portion. If the stomach is distended by carbon dioxide, gurgling or bubbling sounds may be heard at a point distinct from the pylorus, and after this distension two swellings with a notch between can sometimes be made out. Only operative treatment can be effective.

Perigastric adhesions are now well recognized as a mechanical cause of indigestion. There is generally

a previous history of gastric ulcer or biliary colic; the pain is much influenced by the position of the patient and little by diet; and local tenderness is common, while vomiting is rare (E. P. Paton). To this we may add that the X rays show the stomach to be held up somewhere, so that the normal alterations in its position on change of posture or on vigorous contractions of the abdominal wall do not occur.

A woman of thirty-eight was admitted under my care for abdominal pain, situated just below the costal arch, and a little to the left of the middle line. In the eight years previous she had had several attacks of severe pain after food, accompanied by vomiting. For the past few weeks she had suffered from what she described as a ' different pain,' which was ' dragging ' in character, localized, and had no relation to food, but came on as soon as she adopted the erect position. A test-meal showed a total acidity of 0·29 per cent., with presence of free hydrochloric acid. No organisms were found. A skiagram showed that there was no dilatation of the stomach, but that the organ was held up unusually high.

Now, although a succession of gastric ulcers may occur in a young woman, an eight years' history of gastric pain and vomiting in a woman of thirty-eight suggests one chronic ulcer that will not heal. But that active ulceration was still present seemed unlikely in the absence of (1) vomiting; (2) any relationship of the pain to food; (3) marked hyperchlorhydria. It appeared more probable that the symptoms were due

to the result of old ulceration in the form of an adhesion which became dragged upon in the erect posture. Such an adhesion could hardly be in the neighbourhood of the pylorus, for it had led to no dilatation of the stomach. The position of the pain further indicated the fundus as its site.

Mr. Gordon Watson operated and found adhesions surrounding an old ulcer, the floor of which was formed by the anterior abdominal wall. The patient made a good recovery.

I have also seen a perigastric adhesion involving the transverse colon, which yielded an unmistakable skiagram.

Dilated Stomach.—There are important differences between the atonic and the obstructive form of dilatation:

1. *Atonic Dilatation.*—There is sometimes a long history of chronic gastritis. In several of my cases typhoid fever had preceded the symptoms. I have met with instances in which both father and son suffered from it. One of the most characteristic symptoms, which can generally be elicited on inquiry, is that the patient feels full up as soon as he starts eating. Hertz points out that both the atonic stomach and the contracted stomach give rise to this sensation. The contracted stomach feels full up because it cannot expand. The atonic stomach feels full up because it is already dilated, and the normal mechanism, relaxation of the stomach as it fills, to avoid a rise of intragastric pressure, cannot take place. As soon as food

is taken into this relaxed stomach the pressure begins to rise and the patient feels full. After taking food there is a general sense of misery and discomfort rather than actual pain. The patient frequently complains of a disagreeable taste in the mouth, and there is often a brown fur on the back of the tongue, probably due to regurgitation of the contents of the stomach through a relaxed sphincter. There is seldom vomiting. Pyorrhœa is very common. On inspection of the abdomen there may be some dropping of the stomach, a hollowing out under the costal margin, and a fulness below and to the left of the umbilicus.

A succussion splash which is elicited only on deep palpation is only significant at a time when the stomach should be empty. A superficial splash has some significance. It is suggestive of atony, but it is sometimes distinguished with difficulty from the splash obtained in the colon. And neurasthenics and hypochondriacs have an extraordinary power of producing splashing by vigorous contraction of the abdominal walls. The two halves of a seidlitz powder, dissolved separately in water and swallowed, produce a distended resonant area distinctly lower than it should be. The test-meal often shows diminished hydrochloric acid, but by no means always. An atonically dilated stomach gives, on X-ray examination after bismuth, a shadow reaching some distance below the umbilicus, with a broad meniscus at the bottom and a flat upper surface. Peristaltic waves are feeble or absent. Gastro-jejunostomy will not be of any service unless

there is so much dropping that there is actual kinking of the pylorus. Such kinking really adds an obstructive feature to the atonic case, and then there may be some purpose in the operation.

We must distinguish between dilatation and gastroptosis, which is usually part of a general enteroptosis. In the latter the stomach is increased in a vertical diameter, whereas in the dilated stomach it is increased in the horizontal diameter.

Treatment.—Acute dilatation is a dangerous condition of toxic origin, in which treatment appears to be of little avail. Chronic dilatation may exist unsuspected in an alcoholic subject. In the ordinary dyspeptic type there has usually been a long-continued mucous gastritis. I feel that treatment is likely to be very ineffective if lavage be not performed at the outset; otherwise our remedies are apt to be lost in the fermenting slimy mass that is already there. Sodium bicarbonate should be added to the water because of the solvent action of alkalies on mucus. The last part of the fluid employed should have an antiseptic added, such as a 2 volumes per cent. of hydrogen peroxide or a weak solution of potassium permanganate. The best diet is one that will not ferment easily. For this reason starchy foods are contra-indicated; they should certainly never be given in the form of pap, as is so often done. Dry toast, biscuit, or rusk, are preferable, because in the act of mastication some of the starch will become converted into malt-sugar; but any form of starch should be reduced to a minimum.

As Sir Clifford Allbutt says, 'There is no superstition more tenacious of life than that which prescribes carbohydrates to all dyspeptics as "so digestible," and into weak stomachs, ready to dilate, is thrown a mass of such a dish as rice-pudding—a bulky food, imperfectly salivated and peculiarly apt to decompose with the disengagement of volumes of carbonic acid gas.'

In bad cases I have restricted the diet, at first, to meat-juices and meat-extracts (because of their stimulating effect on the secretion of hydrochloric acid), and to lightly cooked minced meat, which does not ferment, and leaves but little residue. From the rapidity with which egg-albumen leaves the stomach it might be imagined that eggs would be a suitable diet in this condition; but patients generally protest that they cannot digest them. After food, hydrochloric acid or acidol should be given, combined with arsenic and strychnine, which seem to have a tonic effect on the gastric musculature.

Abdominal massage is useful as it increases peristalsis in the stomach. Rest after meals should be enjoined, since exercise immediately after can be shown to delay the discharge of food from the stomach. Short advocates keeping the stomach as empty as possible for three weeks, lavage and nutrient enemata being employed.

2. *Obstructive Dilatation.*—The characteristic symptoms are vomiting of large amounts and steadily increasing discomfort between the attacks. After the

stomach has been emptied by a large vomit, the patient is comparatively comfortable for hours or even days, and then discomfort begins and increases until it culminates in vomiting again. A point of practical importance which I have found is that the vomit is highly acid, if the obstruction is not of a malignant nature. Ordinarily, though the secretion of gastric juice may be normal or even slightly hyperacid, the vomit will not show free hydrochloric acid because the conditions which excite vomiting are almost certain to have previously inhibited gastric secretion. But when there is obstruction to the pylorus the vomiting occurs from quite a different reason. Secretion has been taking place as usual, but onward progress and consequent neutralization are delayed so that the vomited contents will be highly acid. A young lady, who had had symptoms of gastric ulcer on two occasions some years before, suffered from paroxysms of vomiting. Between the attacks she seemed quite well. The vomit had an acidity equal to 0·292 per cent. HCl, which is distinctly higher than that shown by the ordinary test-meal removed with the tube. So that I felt sure that, whatever else there was, she had obstruction to the pylorus, which X-ray examination, and finally operation, showed to be the case. When there is obstructive dilatation, X rays show vigorous peristaltic waves twisting about in the stomach, but no onward progress of the bismuth into the duodenum.

Here the operation of gastro-enterostomy is definitely indicated.

Gastro-Enterostomy.—Increased knowledge of the gastric movements has shown clearly the limitations of this operation. It does not 'drain' the stomach. In quadrupeds and in man lying on his left side the pylorus is the highest point, and yet the stomach empties itself. Even when the body is upright and the gastro-enterostomized stomach is filled with water, the water does not run out, because the hydrostatic relations in the abdomen counteract the effect of gravity. Material does not move along the alimentary canal unless the pressure is greater on one side than on the other, and for this muscular contraction is necessary. Kelling performed gastro-enterostomy on dogs by all known methods. At the same time he made a duodenal fistula, which enabled him to observe that nothing escaped by the new opening or ostium. Even when the pylorus was partly occluded, the food passed through it rather than through an opening remote from the greatest pressure. Berg operated on two cases of duodenal fistula, and had a similar experience. In both gastro-enterostomy was done, but the discharge of chyme through the fistula ceased only in one in which he tied the pylorus as well. We are not justified in assuming that the region between the new opening and the pylorus is placed completely at rest. The full benefit of the operation is therefore obtained only in cases of definite obstruction to the pylorus. There is no doubt, however, that chronic ulceration with recurrent hæmorrhage has been benefited by it even when there was no pyloric obstruction. To under-

stand this, we must bear in mind the effect of the hyperchlorhydria associated with gastric and duodenal ulcer. Bolton has proved experimentally that hyperacidity facilitates the production and prevents the healing of a gastric ulcer. One of the actions of the acid when it enters the duodenum is to cause closure of the pyloric sphincter, which lasts until the pancreatic juice has neutralized it. Excessive acidity provokes excessive contraction, thus keeping the acid in contact with the ulcer, and increasing the pain. Further, by keeping the chyme in contact with the pyloric glands the continued secretion of acid is stimulated. Thus, the excessive acidity causes pyloric spasm, while the spasm leads to increased acidity. The most intense pyloric spasm I have ever seen has been in fatal cases of hydrochloric acid poisoning. This spasm is responsible for the invariable occurrence of ulceration and ultimate stenosis in the neighbourhood of the pylorus in patients who survive long enough.

After gastro-enterostomy hyperchlorhydria usually passes off, though in exceptional cases a jejunal ulcer may follow, showing that the acidity has persisted. The diminution in acidity results from: (1) Regurgitation of alkaline bile and pancreatic juice into the stomach through the new orifice, which is not provided with a sphincter. (2) Absence of the chemical stimulant to gastric secretion, since the food is not kept in contact with the pyloric glands. That the secretion is diminished and not merely neutralized is shown by the reduction of the total chlorides in the

gastric juice. Retention of food in the stomach with repeated vomiting, the so-called ' vicious circle,' is an occasional bad result of the operation. This is not due to the repeated entrance of the food from the duodenum into the stomach, but to an obstructive kink or other demonstrable obstacle. Although, according to Cannon, sharp turns in the intestine are normally straightened without difficulty by the material driven on by peristalsis, this force is not at hand to straighten a kink immediately beyond the ostium. For the division of the circular muscular fibres at the operation has abolished the peristaltic wave there. The rational procedure is therefore to attach a narrow band of the distal gut continuously to the stomach wall for an inch or so beyond the ostium. The gut is then kept straight throughout a distance which permits peristalsis to become an effective force. When food passes into the proximal loop, as it often does, a peristaltic wave starts which drives it back again into the stomach, for as the circular muscular coat of the gut is not complete at this point, it is not driven into the distal gut. This must, at any rate, mix some of the food thoroughly with the digestive secretions poured into the duodenum. Distension of the stomach will also interfere with the proper action of the ostium by flattening out the gut wall until the entrance into the lumen of the intestine is changed into narrow slits.

Another unfavourable result may be too rapid drainage of the stomach as shown by Hertz. The chief

symptom complained of is a feeling of fulness slightly lower down than the site of the discomfort before the operation. The distension of the jejunum is probably responsible. The patient has generally found that a dose of castor-oil shortens the duration of this discomfort, because it hastens the onward progress of the contents of the distended jejunum. Hertz advises the recumbent posture after meals in these cases to delay the emptying of the stomach. If this is not sufficient, small doses of belladonna to relax the muscle-fibres of the intestine, and of codeine to diminish the excitability of the sympathetic nervous system, should be given half an hour before meals. Another exceptional cause of continued trouble after gastro-enterostomy is that the opening may have been made above the upper level of the gastric contents. This can be overcome by an abdominal support, and by the recumbent posture on the left side after meals.

The possibility of these various untoward consequences renders the operation far from an ideal one, but if the principles laid down here are followed, great benefits may be obtained in suitable cases.

Congenital Hypertrophic Stenosis of the Pylorus.—This cause of vomiting and marasmus in infants presents some interesting problems. The diagnosis rests upon the combination of vomiting, constipation, and wasting with visible peristalsis of the stomach and a palpable pylorus. The symptoms are rarely congenital, the vomiting usually beginning about the fourth week, and not later than the ninth week, after

birth. It is generally sudden, copious, and forcible, so that a quantity representing more than one feed may be shot out a foot or more from the mouth, and perhaps through the nostrils also. With increasing dilatation the vomiting becomes less frequent, while the amount becomes greater. For the two characteristic signs of visible peristalsis and palpable pylorus, Still lays great emphasis on the importance of examining the abdomen immediately after feeding. It is then, and sometimes only then, that the abnormal peristalsis can be seen, and that the thickened pylorus can be felt. It may be necessary to examine for ten to fifteen minutes before the signs can be elicited. Sometimes the waves appear spontaneously, at other times only after repeated stroking or gentle kneading of the epigastrium. Post mortem the stomach is found greatly dilated, and the pylorus is much thickened for about $\frac{3}{4}$ inch, yet a probe can usually be passed through it readily. Microscopically, the only change found is hypertrophy of the muscular tissue.

The pathology of the condition is a vexed question. Congenital stenosis appears to be a misnomer, since the hyperplasia occurs after birth, and there is no true narrowing of the lumen. Pyloric spasm leading to muscular hypertrophy seems to be the sequence of events. But what causes the spasm? In adults the most fertile cause of such spasm is hyperacidity, but this is not found here. Miller and Willcox think that the excess of rennin may play a part by causing a large curd to form rapidly in the stomach, which would

excite pyloric spasm by its bulk. John Thomson suggests that the spasm is due to a muscular incoordination of the muscles of the stomach, the central nervous system having not yet acquired proper control. It would thus be comparable to the stuttering of a child who is learning to talk. Edkins has made the interesting suggestion that this spasm, like many others, is protective. If there were pancreatic inadequacy, the acid, passing into the duodenum, would not evoke secretion from the gland, and would not be neutralized. The pyloric sphincter would, therefore, be kept firmly contracted. In this way food is prevented from entering a region where it could not be properly digested. In support of this hypothesis it may be pointed out that in young infants pancreatic inadequacy is the rule, so far as the starch-splitting ferment is concerned, and an extension of this inadequacy to the other constituents of the juice is a plausible conjecture. The bad effects of removing the obstruction by operation supports this idea.

Treatment.—This will have to be prolonged, and will call for much patience on the part of all those concerned. It is important to give only small quantities of thin food, so as to avoid any distension of the stomach and any residue. At first whey and raw-meat juice only should be given. The amount at each feed should be a teaspoonful every twenty minutes at the outset, and this should be only slowly increased to two, three, or four teaspoonfuls at longer intervals. If milk be used, it should be citrated to

prevent curdling. On the view just expressed complete pancreatization of the food might be helpful. Some observers are in favour of stopping all food by the mouth for a time; they believe that this enables the spasm to subside. But diet alone is hardly likely to lead to success. Systematic lavage must also be employed. Still's plan is to have the stomach washed out just before a feed twice daily for several weeks, and then once daily for several weeks longer, with a solution of sodium bicarbonate (2 grains to the ounce) through a Jacques' soft catheter, No. 12 or 14. This must be continued until not only the vomiting has stopped, but till the weight is steadily increasing.

Minute doses of opium ($\frac{1}{80}$ minim of the tincture) have been recommended by Newman Neild as helping to overcome spasm. Forcible dilatation, pyloroplasty, and gastro-enterostomy, are various operative methods that have been employed, but they all have grave risks, both at the time from shock, and subsequently from the diarrhœa which so often follows. This is probably due to the atrophic intestine, or perhaps the inadequate pancreatic secretion, which is unable to deal with any large amount of food after the obstruction has been removed. 'The infant's life hangs in the balance for several weeks after operation.' This being so, we should not resort to surgery until it is clear that lavage and dieting will not relieve the vomiting and the wasting.

The Intestines.

Discharge of Food into the Duodenum.—As has already been pointed out, the pyloric sphincter is controlled by the secretion of HCl. Thus the food is held in the stomach until provision is made for the continuance of gastric secretion, until the gastric juice has had time to act, and until the food can carry with it the acid needed for processes in the duodenum. But as water excites no gastric secretion, it begins to leave the stomach almost as soon as it enters. This quick exit before it is acidified doubtless explains the readiness with which it conveys infection, the acid being antiseptic. The slow discharge of fats from the stomach is explained by the fact that not only do they inhibit secretion there, but when they begin to be digested in the duodenum they give rise to fatty acids which will help to keep the pylorus closed. Consequently, they leave only as fast as they are absorbed by the small, or carried into the large, bowel. They are almost invariably present in the stomach seven hours after ingestion.

The discharge of the gastric contents may be reflexly delayed in another way. Murphy and Cannon found, after high intestinal section and suture, that for almost six hours after recovery from anæsthesia, the pylorus remained tightly closed. There is a remarkable coincidence between the period of delay in the discharge and the period required for the primary cementing of the intestinal wound. This is clearly protective, and

probably explains the spasm and consequent hyperchlorhydria of reflex dyspepsia. It may occur in duodenal ulcer and in diseases of the biliary passages, both of which we know are accompanied by hyperchlorhydria, a necessary result of pyloric spasm. This occurs also when the colon is irritated, and it has become recognized of late that hyperchlorhydria is an almost invariable accompaniment of colitis, and frequently results from chronic appendicitis.

Movements of the Small Intestine.—These are of two kinds: (1) Pendulum (Bayliss and Starling) or segmentation movements (Cannon) which travel at the rate of 2 to 5 centimetres a second, and depend on muscle tone. They cannot move the contents along, but serve to mix them thoroughly by forming a number of alternately constricted and dilated areas, each of which is divided exactly into two by the next movement. (2) Peristaltic movements, a powerful wave of constriction following immediately on a wave of dilatation, so that the contents are always being driven from a contracted into a dilated area. These waves depend on an intrinsic nervous mechanism of the bowel, the plexus of Auerbach. At the same time the extrinsic nerves affect these waves, the vagus increasing and the splanchnic inhibiting them. An exception to this general statement is the fact that the splanchnic nerve supplies motor fibres to various sphincters. Elliott has formulated the law of the hollow viscus as follows: 'If the quiet lodgment of the contents be facilitated by the presence of sympathetic inhibitory

nerves to the body of the viscus, there will also be sympathetic motor nerves at the sphincter closing the exit.' The pylorus, the ileo-cæcal valve, the internal anal sphincter and the neck of the gall-bladder are all thus supplied.

Extrinsic mechanisms occasionally interfere with the normal intrinsic ones, usually in the direction of inhibition. This is observed after operations. It has been shown that even gentle manipulation of the stomach and intestines produces a much greater post-operative inactivity than anything else in the operation. That this is due to reflex inhibition is proved by the fact that it is overcome for a time by injection of eserine salicylate ($\frac{1}{100}$ grain four hourly for six doses) which diminishes these nervous influences, while tincture of aloes, which is particularly effective in promoting peristalsis in the cat, is quite ineffective after such manipulation of the gut as results in paralysis. Many emotional states are a strong stimulus to peristalsis, while others inhibit it. Thus in most animals any sign of rage or distress or mere anxiety is accompanied by a total cessation of the movements of the stomach. In the dog's intestine on the other hand, after signs of emotion there is a marked increase of activity lasting for only a few minutes. Emotion as a factor in the production of diarrhœa is well-known.

Apart from operative interference or organic obstruction delay seldom occurs in the small intestine. Cannon never observed it experimentally, and Hertz

found it only in lead-poisoning. Peristaltic rush, on the other hand, is not infrequent here, and may be the result of a purgative or an enema. Of the three foodstuffs, carbohydrates normally pass the most rapidly. This may be associated with the presence of cellulose and its well-known mechanical action. Cannon noted that normally the peristaltic wave can force the contents past kinks and sharp bends without difficulty, an observation which has an important bearing on Arbuthnot Lane's views of intestinal stasis. Owing to the comparatively dilute condition of the contents of the small bowel the movements of segmentation and peristalsis are not so clearly seen with the X rays as in the stomach and colon. After an ordinary meal the average time for the shadow to appear in the cæcum is four and a half hours (Hertz), so that the rate of progress through the $22\frac{1}{2}$ feet of small intestine is rapid.

Cannon also made some interesting observations on the result of intestinal anastomosis. After an end-to-end union of the intestine there was no evidence of stasis, but after lateral anastomosis there was a more or less complete blocking. In time the tube may be straightened out after a lateral anastomosis, with restitution of functional efficiency, but there is a period when there is a danger of obstruction, because the division of the circular coat of muscle interferes with peristalsis. Further, if the blind ends of the lateral loops are allowed to extend beyond the openings there is a danger of the proximal portion becoming

packed with hardened fæces, and of the distal becoming invaginated until it fills the lumen of the anastomosis.

Movements of the Large Intestine.—Functionally the large intestine can be divided into three portions which do not correspond exactly to the anatomical divisions: (1) a proximal part characterized by the presence of antiperistaltic waves, (2) an intermediate part conforming to the type of movements seen in the small intestine, and (3) a distal portion, the rectum, where the central nervous system again assumes control. It is in this last part that disturbances are most likely to occur because the automatic call for the discharge of its contents can be voluntarily suppressed. Antiperistalsis is rather a misnomer, for it is really a rhythmical series of reversed segmentation movements and not peristaltic waves originating from a ring of tonic constriction, and depending largely on the degree of tension present. It serves to churn and delay the onward passage of the food. It necessitates a true muscular sphincter at the ileo-cæcal valve, and the development of a cæcum is a corollary to its occurrence. In animals like the rabbit and the herbivora in general, where the cæcum is long, it can be filled only by the aid of antiperistalsis. This also accounts for the fact that the emptying of the cæcum is never complete.

In the large bowel the absorption of water mainly occurs, and as the contents become more solid, the shadow cast on the X-ray screen becomes more intense, so that the segmentation waves and peristalsis become very distinct. The onward progress also

becomes much slower, so that the colon is traversed in about six hours. During the night the movements are considerably slower than this. According to Hertz, the entire large intestine below the splenic flexure is normally evacuated at a single act of defæcation. The action of some purgatives in producing peristaltic rush in the large intestine is marked. Thus senna causes an evacuation as soon as it enters the colon, and anti-peristalsis is completely inhibited. Enemata, on the other hand, have a markedly stimulating action on the antiperistalsis of the colon. Small rectal injections are never forced even partially into the small intestine; but with larger amounts, whether fluid or semi-solid, many coils of the small gut become filled. In cases of cæcal fistula the ileum has been transplanted into the transverse colon without stopping the discharge, for here, as elsewhere in the alimentary canal, the contents will continue to follow the direction of the powerful muscular waves which will be very incomplete where the circular coats have been divided. This has an important bearing on short-circuiting operations designed to exclude the large bowel. If the normal path be left open, much of the contents will continue to pass along it. Lockhart Mummery considers that occlusion of the colon, either partial or complete, usually is not compatible with permanent good health. Accumulation of fæces occurs sooner or later in the occluded loop, and causes trouble which, if unrelieved, produces auto-intoxication and possibly abscess or perforation.

Defæcation.—Approximately nine hours after ingestion material enters the descending colon, and remains there until the next action of the bowels. This means, as Hertz has pointed out, that when the bowels are opened regularly once a day the interval between a meal and the excretion of its residue will vary between nine and thirty-three hours. As the pelvic colon becomes distended it rises, widening the acute angle with the rectum, thus removing an obstacle to the onward progress of the contents. The rectum should normally be empty, except during the act of defæcation, but in constipated persons it always contains some fæces. The first meal of the day evokes peristaltic waves throughout the whole alimentary tract, driving some of the contents of the sigmoid into the much more sensitive rectum. It is distension of the rectum which evokes the desire to defæcate, which may be produced either by the passage of fæces from above or by a balloon introduced through the anus. The distension may be increased voluntarily by contraction of the abdominal muscles of the walls. A powerful wave of peristalsis is thus produced in the rectum, and the discharge of contents is facilitated by the recto-coccygeus muscle, which draws the rectum backwards, straightening out the angle in its lower portion, while the anal sphincters are relaxed. The levator ani mainly acts as a voluntary sphincter, but it may also help in defæcation by directing the fæces forward towards the entrance to the anal canal, and by drawing this canal upwards over the fæcal mass,

and finally contracting firmly behind it. In multiparous women injury to, and atrophy of, the levator ani play a distinct part in the production of constipation. Again, the levator ani being a voluntary muscle can resist the call to defæcation. When this occurs the desire soon passes off until the arrival of more fæces again distends the rectum. Repetition of this process blunts the sensibility of the rectum until it habitually retains a considerable amount of fæces. Although such a patient is constipated, X-ray examination shows that there is no delay in the onward passage of the intestinal contents until the rectum is reached. For this type of constipation Hertz has revived the term *dyschezia*, originally used by Robert Barnes to denote painful evacuation of fæces. As he points out, there is little use in treating such a case by aperients, which have to act on a colon which is normal in its response. The rational procedure is the routine use of enemata, by which the rectum can be emptied and its tone regained.

In Hirschsprung's disease, often erroneously called a 'congenital idiopathic' dilatation of the colon, the rectum is not involved in the dilatation. The hypertrophy of the muscular coats of the colon shows that atony is not the cause, but that there must primarily be an obstruction. This, according to Hertz, is primarily fæcal, as a rule, though in rare cases it may be spasmodic. Once the colon becomes dilated, it produces a kink by overhanging the undilated part below. The obstruction is thus maintained even when

the impacted fæces originally present have been evacuated. As this obstruction can be seen only when the parts are in position, the failure to discover it *post mortem* is explained, since there is no organic stricture. In the same way it may not be detected at operation, since the laparotomy allows the dilated colon to rise out of the abdominal wound, which relieves the obstruction for the time being. Blochmann urges that there is a valvular obstruction usually produced by a congenital kinking at the junction of the pelvic colon with the rectum. On the view put forward above, the kink is not congenital, but results from constipation in the first instance. In treatment the most important thing is to empty the colon as completely as possible by enemata, and then to prevent its becoming overloaded again by the use of a rectal tube passed above the kink. If this cannot be done a laparotomy will allow of the distended colon being pulled upwards, and the tube can be passed. Strychnine and abdominal massage are valuable adjuncts to treatment. The radical operation of removal of the colon is fraught with grave danger to life. Hertz advises its performance in three stages: First, a colostomy; secondly, an anastomosis between the ileum and the undistended rectum; and finally, a colectomy, if necessary. In any case, the prognosis is unfavourable once the condition is thoroughly established.

Intestinal Stasis and its Consequences.—A new interest has been aroused in the mechanical factors in digestion by Sir Arbuthnot Lane's work on viscerop-

tosis and intestinal stasis. The very enthusiasm with which he has advocated his views has perhaps tended to excite opposition. However, considerable evidence has now been accumulated by independent observers, who were sceptical at first. Probably while the more extreme parts of his doctrine will not command assent, his main contention will gain increasing support. He holds that the main cause of visceroptosis is the adoption of the erect posture, while contributory factors are the stretching of muscles and the relaxation of ligaments due to repeated pregnancies, tight lacing by wrongly constructed corsets, lifting of heavy weights, emaciation, and muscular debility. He also attaches considerable importance to the customary sitting posture adopted during defæcation by civilized races as contrasted with the primitive squatting attitude, as helping to force the viscera down into the pelvis. It will be noted that many of these causes are more operative in women, in whom the condition is much commoner than in men, in whom the lesser obliquity of the pelvic brim also affords more support to the viscera. The three principal results of this visceroptosis are, according to Lane, (1) the formation of conservative adhesions along the lines of resistance to downward displacement, (2) the consequent production of kinks along the course of the gastro-intestinal tract, leading to (3) stasis, with delayed digestion, constipation, and auto-intoxication.

The *adhesions* are not the result of inflammation, but are developed where the mesenteric attachment has

been dragged upon to counteract the dropping of the viscera. The existence of such adhesions has long been known, but the interpretation is new. They may occur (1) between the pylorus and the under surface of the liver in front of its transverse fissure, extending along the cystic duct and gall-bladder; (2) between the outer aspect of the cæcum and the adjacent abdominal wall; (3) between the hepatic flexure and the right kidney; (4) between the descending colon and the abdominal wall; (5) fixing the sigmoid loop to the brim of the true pelvis. On the other hand, the splenic flexure is naturally well supported by the costo-colic ligament, which may become thickened as the downward drag increases.

The *kinks* may form (1) at the pylorus in consequence of the first of the adhesions described above, causing delay in the emptying of the stomach; (2) at the junction of the duodenum with the jejunum, resulting from the end of the duodenum being firmly fixed by a peritoneal band, while the freely mobile jejunum drops; (3) at the ileo-cæcal junction due to prolapse of the cæcum into the pelvis while the ileum is held up by a thickened layer of mesentery; (4) at the appendix by an acquired mesentery, which leads to the distal part being sharply flexed on the proximal part; (5) at either end of the transverse colon by adhesions to the right kidney at one end, and by the costo-colic ligament at the other, while the gut in between drops, and (6) in the sigmoid, where it becomes adherent to the brim of the true pelvis.

A large number of symptoms have been referred by Lane and his followers to intestinal stasis—a poor appetite and a bad taste, offensive breath, flatulence, constipation, attacks of nausea and vomiting, and frequently abdominal pain with points which are tender to pressure. The general effects of the intoxication are seen in the depression and want of energy, both mental and physical. The circulation is impaired, the hands and feet are cold, clammy, and often livid, the skin loose and inelastic, becoming pigmented. Progressive emaciation, headache, backache, muscular pains and aching joints are not uncommon. In women the breasts show the changes of chronic mastitis, and often undergo cystic degeneration. Without going into the more remote effects assigned to this cause, which, starting with diminished resistance to tuberculous infections, threaten to extend until every ailment and lesion are thus explained, we may note the ingenious way in which the theory is made to account for many diseases of the alimentary tract and its annexes. The mechanical retention of stomach contents causes them to become more acid, from continued secretion, which may be a potent cause of erosion and ulceration of the gastric mucosa. The mucous membrane of the 'kinked' duodenum becomes congested and then ulcerated. On this view gastro-jejunostomy is not a rational treatment for duodenal ulcer, and Lane holds that it benefits only by anchoring the mobile jejunum in such a way that it cannot kink upon the fixed duodenum. In many cases the kink is slight

enough to be got over by lying down after meals. Duodenal ulcer can often be treated successfully by rest and medical means, and the absolute rest necessitated by the operation no doubt plays an important part in the good results attributed to it. Ascending infections of ducts can occur more readily when as a result of stasis bacteria normally confined to the large intestine ascend into the ileum, and so gall-stones and pancreatitis are explained. As has been already said, Lane holds that adhesions round the appendix are more frequently the cause than the result of appendicitis. Mucous colitis is referred to similar causes, and carcinoma of the intestines is held to result from irritation due to material passing along the various kinks and flexures.

Such sweeping conclusions have naturally aroused opposition. It must be remembered that Cannon found that peristalsis was able to drive on the contents of the bowel past quite sharp kinks, and in tuberculous peritonitis, or malignant disease of the intestines kinks are formed which in many cases produce neither constipation nor stasis. There is a muscular sphincter of some length at the ileo-cæcal valve, which might easily produce the appearance of a narrowing by adhesions, and as the bismuth shadow is often seen to be as intense on the distal as on the proximal side of the ' kink,' it cannot always mean a definite obstruction. Again, in healthy persons, the transverse colon may be quite as low as in cases of visceroptosis, without any symptoms. But when a number of observers agree that they can recognize the condition by its

symptoms, that it can be confirmed by X-ray examination and subsequently at the operation, and that it can be cured by short-circuiting, and that the patients remain cured, it is hard to see what further proof can be demanded. That extravagant claims are being made does not disprove the main contention. The radiographic evidence adduced by A. C. Jordan in support of Arbuthnot Lane's views cannot be lightly brushed aside.

Treatment of Visceroptosis.—Prophylactic measures include the inculcation of regular habits as to the bowels, starting in childhood and continued throughout life, the use of low lavatory seats, or of footstools high enough to allow of a squatting posture during defæcation, not lifting heavy weights or getting up too soon after debilitating illnesses and confinements, the avoidance of corsets exerting a downward pressure, and the correction of a tendency towards emaciation. Besides the ordinary measures for the relief of constipation special mention must be made of liquid paraffin, which has lately acquired such a vogue in the treatment of constipation. Not being absorbed, it increases the bulk of the fæces, and really does seem to facilitate the onward progress of the intestinal contents. The drawback to its use is that in some cases it produces a slight degree of incontinence; but this is generally because too large an amount has been taken. I therefore start by prescribing quite a small dose, such as a drachm, and increasing slowly till the quantity suitable for the individual has been found, which may be an ounce or more. Some preparation of Iceland

moss, such as regulin, prescribed at breakfast time with some cream, by its power of absorbing water and swelling up, is useful occasionally to increase the bulk of hard dry fæces; but I have not found it as effective as paraffin, while other observers have sometimes found it to cause troublesome accumulations in the cæcum. Abdominal massage and exercises designed to develop the abdominal muscles may be helpful, though in some of the worst cases of ptosis the abdominal walls are quite good, the movement of the viscera being downward and not forward. A well-fitting abdominal support, of which I believe the best to be Curtis's, is often of great assistance. It might be thought that such a support can only do good, and should only be worn when the abdominal muscles are so weak that they are unlikely to recover. Such, however, is not my experience, and Hertz believes that the good effect of the support is due to its increasing the intra-abdominal pressure rather than to its replacing any particular viscus. He regards a disturbance of the balance between the thoracic and abdominal pressures as one of the main factors in inducing visceroptosis, and thinks that if the drag on the viscera is prevented, the patient is enabled to eat more without fear of discomfort, and to take more exercise, thus helping to overcome the sluggish action of the intestines. If all these points are carefully attended to, surgical interference will not often be required. When the X rays show pyloric spasm and delay chiefly, or solely, at the cæcum, I think the

appendix is generally responsible for the symptoms, and its removal may be indicated.

As to other operative measures, only in exceptional cases is the mere division of constricting bands to be advised. If divided they are apt to recur, and, as has been already pointed out, their formation is compensatory. Arbuthnot Lane prefers to divide the ileum near its lower end, and short-circuit the divided end into the upper part of the rectum. He believes that some of the unsatisfactory results in his earlier cases were due to lateral anastomosis, the mechanical disadvantages of which have already been pointed out. But in any case the conversion of the whole of the colon into a cæcum is open to the objection that it is likely to become impacted and dilated. This has occurred in some cases, for which he has carried out resection of the whole of the large bowel. Such a drastic operation is certainly to be avoided if possible. Nevertheless, good results have been recorded.

W. E. Miles has put forward another view as to the production of intestinal stasis in women, in whom, of course, the symptoms are much more common. As a result of the general sliding down of the posterior wall of the peritoneum, there is a proptosis of the broad ligaments. On the left side this tends to obstruct the pelvic colon where it passes over the shelf formed by the ligament which has assumed a horizontal instead of a vertical position. Adhesions form and still further add to the obstruction. The prolapse of the ovary and Fallopian tube into Douglas's pouch at the same time

may set up pelvic symptoms, which do not now concern us. Miles believes that if this obstruction is removed by obliteration of the left broad ligament, the rest of the alimentary canal will recover its tone, even though there may also be dropping of the stomach and transverse colon. He instances two cases in which gastro-jejunostomy had failed to relieve the gastric symptoms, but this obliterating operation was successful. That there is a demonstrable pelvis shelf in these cases is certain, but it is not claimed that its mere rectification will cure, since he adds that 'it is essential that a course of intestinal lavage combined with the daily use of suitable aperients, should be persisted with for several months afterwards.' He perhaps attributes an excessive share of the improvement to the operation.

Some scepticism is natural when one recalls the number and variety of the surgical short cuts to health that have been advocated, and the disillusion that has too frequently followed. Appendicectomy, gastro-jejunostomy, intestinal short circuits, and rectification of the pelvic shelf all have their use in suitable cases. There has been, however, a regrettable tendency of the advocates of each to regard their particular method as a panacea to the exclusion of all the others. This is part of a generally uncritical attitude seen too frequently in the profession, and one that has been satirized by the observant layman. Only by a close and accurate study of the normal mechanism of the alimentary canal can we arrive at sound conclusions as to the value and limitations of any procedure, medical or surgical.

CHAPTER IV

THE WORK OF THE PANCREAS

Although the pancreas provides the most active digestive secretion in the body, and plays an important part in general metabolism, disease in it is rarely recognized during life. A consideration of the way in which the pancreas does its work may enable us to realize the difficulties attending this recognition, and the steps by which they are being overcome.

As soon as the acid chyme enters the duodenum the secretion of pancreatic juice begins. Its alkalinity corresponds almost exactly to the acidity of the gastric juice, so that, allowing for the alkaline bile, the total bulk of pancreatic secretion will be rather less than that of the gastric secretion.

Von Mering has shown that injection of acid into the duodenum leads to closure of the pyloric orifice. Not until this acid has been neutralized by the pancreatic juice it has produced can more of the acid contents of the stomach pass through the pyloric sphincter. The secretion is thus exactly regulated to the amount of food arriving from the stomach.

Pawlow thought that the acidity of the chyme

acted by stimulating special nerve-endings in the duodenum, but Wertheimer showed that the acid was equally effective after section of all the nerves in the neighbourhood, or even after extirpation of the solar plexus. The acid produced less effect the further down the intestine it was introduced, until within two feet of the ileo-cæcal valve it ceased to have any effect at all. This paved the way for Bayliss and Starling's important discovery that the hydrochloric acid of gastric juice, when it comes into contact with the mucous membrane of the intestine, leads to the production of a chemical stimulant, *secretin*, which is absorbed from the cells by the blood-stream and carried to the pancreas, where it acts as a specific stimulant to secretion.

Dilute hydrochloric acid was placed in a loop of jejunum which had been previously isolated from the rest of the body except for its blood-supply. The absorption of acid was accompanied by a secretion of pancreatic juice. If, however, the acid were injected direct into the blood-stream, it was ineffective. On the other hand, a saline extract of the intestinal mucosa treated with hydrochloric acid and injected into the blood-stream produced an active secretion. Thus, for pancreatic secretion to occur normally, hydrochloric acid must descend from the stomach, which will only happen in the presence of food.

For some years after this discovery it was generally believed that this chemical mechanism is sufficient to account for all the facts of pancreatic secretion.

Clayton-Greene has, however, recorded a case which seemed to point to a nervous control. During pylorectomy for malignant disease of the stomach a pancreatic fistula was accidentally formed. A few seconds after food was swallowed pancreatic juice began to appear, and this occurred even when the food had only been seen and not swallowed. Nervous mechanisms are distinguished from chemical by their speed, and here the reaction was extremely rapid.

In 1911 Cathcart obtained pancreatic secretion in animals by vagal stimulation; so that, while the main stimulus is chemical, we must admit a nervous factor as well. It may be safely asserted that after severance of all nervous ties secretin can produce a copious flow of pancreatic juice. Comprehension of this chemical factor brings the regulation of pancreatic digestion much more under our control.

Inadequate pancreatic secretion appears to have a striking effect upon growth. Byrom Bramwell has described a condition of persistent infantilism due to this on a lad of eighteen, who did not look more than eleven. He was perfectly formed, bright, and intelligent. His height was 4 feet 4 inches, and his weight 4 stone $7\frac{1}{2}$ pounds. He had suffered from diarrhœa for nine years. The abdomen was swollen and tympanitic. Skiagrams showed that the epiphyses, which should have united between sixteen and eighteen, had not done so. There was no glycosuria. The pancreatic secretion was found to be defective or absent by tests described later. Marked improvement

followed treatment by a glycerine extract of the pancreas. The diarrhœa greatly diminished; he grew $5\frac{3}{8}$ inches in two years, and increased 1 stone 8 pounds in weight, although previously he had not grown for eight years. Signs of puberty, till then entirely lacking, now developed.

Here profound disturbances resulted from pancreatic inadequacy, yet there was no glycosuria, suggesting that it was only the external secretion of the pancreas, and not the internal secretion, that was at fault. I have seen a case of severe congenital syphilis in a boy of sixteen, combined with persistent infantile features. In appearance he looked about eight or ten years old, and all signs of puberty were lacking. Now, congenital syphilis is known to lead to arrested bodily development, but the special feature of interest here was the existence of fatty diarrhœa, suggesting pancreatic inadequacy. There was no glycosuria. At the post-mortem examination the condition of the pancreas typical of congenital syphilis was found. The condition closely resembles, however, the infantilism described by Herter as due to a chronic intestinal infection characterized by an overgrowth and persistence of the flora of the nursling period.

Why does not the pancreas digest itself? It was long a problem why the digestive organs, themselves composed of protein tissues, should resist digestion by their own ferments. In the case of the stomach, the fact that the juice only acts in an acid medium, while the blood is alkaline, was held to explain the

difficulty. But this only made the case of the pancreas all the more striking. Now, however, we are provided with a satisfactory answer to the riddle. The tryptic activity of the pancreas is hedged around with some remarkable safeguards.

1. *Active trypsin is normally liberated only in the presence of food.* As stated, hydrochloric acid is the stimulant to pancreatic secretion, and this will pass into the duodenum only as the result of food leaving the stomach.

Moreover, fresh pancreatic juice contains inactive trypsinogen. Before this can become active trypsin, it must be acted upon by another ferment, *enterokinase*, which appears to be present only in the succus entericus. Therefore the fluid present in the duct of Wirsung cannot injure the gland, for it is inactive until discharged from the papilla. And although any mechanical irritation of the intestine will lead to the outpouring of mucus, true succus entericus is secreted only in the neighbourhood of the food; while, according to Pawlow, its richness in enterokinase depends on the stimulating action of the pancreatic juice. Whatever the exact stimulus to succus entericus may be, it is difficult to extract enterokinase from the intestine of a fasting animal, so that its presence seems to be dependent on the food. This ' double locking ' insures that under normal conditions active trypsin can be liberated only in the presence of food.

The importance of these safeguards is seen on injecting secretin into fasting dogs. Then active pan-

creatic juice is set free, and the intestinal walls are extensively digested.

2. *Trypsin is an unstable body, and rapidly destroys itself, if proteins or their products are not present.* In this way trypsin left over at the end of digestion is soon disposed of.

3. *The blood-serum contains an antibody to trypsin*, thus destroying any ferment which may accidentally enter the circulation.

Trypsin is no exception to the general rule that the introduction of a substance of the protein class into the circulation excites the formation of the appropriate antibody. It is interesting that intestinal worms also contain an antitrypsin. This explains at once their power of living in the intestine and the voracious appetite of their host, who is thus largely incapacitated from assimilating proteins.

For these reasons it is difficult to understand how pancreatic hæmorrhage or necrosis can be due to self-digestion of the gland by trypsin. But probably other things besides enterokinase may be capable of activating trypsinogen. After all, a ferment merely carries out with great velocity, and at the temperature of the body, a reaction which can be performed, though much less readily, by other means.

Delezenne claims that calcium salts can activate trypsinogen, as we know they do fibrin ferment. A pre-existent pancreatic catarrh might lead to the formation of active trypsin within the ducts of the gland; pancreatic calculi, for instance, are rich in

calcium salts. Guleke believes self-digestion by trypsin to be the cause of the toxic symptoms in acute necrosis of the pancreas. He produced similar symptoms by transplanting the pancreas of one dog into the peritoneal cavity of another, and the same constitutional effects by intravenous, intraperitoneal, or subcutaneous injections of trypsin. The animal could, however, be partially immunized against the effects of transplantation by injections of gradually increasing doses of trypsin.

Laparotomy for a ruptured pancreas has been followed by rapid digestion of the rectus abdominis in the neighbourhood of the wound. As no injury to the duodenum was found at the necropsy, there could hardly have been activation by enterokinase. The drainage of pancreatic cysts, too, has occasionally been followed by extensive self-digestion along the track of the fluid.

But such cases are exceptional, and the usual cause of the necrosis is probably the passage of infected bile back along the pancreatic duct. As normal bile will not activate trypsinogen, the effect is probably due to some septic infection of the bile. The best treatment for inflammatory conditions of the pancreas is drainage of the gall-bladder, so as to prevent infected bile from coming into contact with the inflamed tissues (Mayo Robson).

Fat Necrosis.

With regard to steapsin the case is different; should the juice be extravasated from the gland, digestion

of the body-fat will follow. 'Fat necrosis' is due to this splitting of the body-fat into glycerine and fatty acid, the latter combining with lime salts. Flexner has demonstrated the presence of steapsin in the affected areas, while Opie was able to show its presence in the urine in one such case by its decomposing action on ethyl butyrate.

These opaque white areas, often surrounded by a ring of inflammation, are usually most abundant in the neighbourhood of the pancreas and omentum, which suggests that they are caused by direct extravasation of the steapsin.

Cammidge's 'pancreatic reaction' is founded on the belief that there is a large proportion of a pentose-yielding substance in the pancreas, so that in disintegration of the gland we might expect to find it in the urine. But the Mayo clinic conclude that, 'if knowledge of the clinical histories and other factors of the personal equation be eliminated, the end-results, judged by Cammidge's own criteria, must be considered, as a means of diagnosing disease of the pancreas, both valueless and misleading.' This reflects the conclusion reached by many other workers.

Other Pancreatic Ferments.

Pancreatic juice can act on all three classes of foodstuffs. The starch-splitting ferment, amylopsin, only differs from ptyalin in saliva in being more rapid and in being able to act on unboiled starch. Were amy-

lopsin to enter the circulation, it could do no harm beyond digesting the glycogen in the liver. This could not account for pancreatic diabetes, since the glycosuria does not cease with the emptying of the glycogen reservoirs, and is most intense after total excision of the pancreas.

Pancreatic juice also contains small amounts of erepsin, which completes the digestion of proteins, a milk-curdling ferment, and a malt-sugar-splitting ferment. But they are of subsidiary importance here, being more abundantly present in other digestive secretions.

It was formerly thought that the pancreatic juice was adapted to the character of the food by variations both in the quality and quantity of the different ferments. This seems to have been disproved; everything points to secretin being a definite chemical entity which stimulates all the ferments alike in pancreatic juice.

It is unnecessary to say anything about the treatment of malignant disease by injection of trypsin, the method having passed into the limbo of deservedly forgotten ' cancer cures.'

The Influence of the Pancreas on General Metabolism.

Since the classical experiments of von Mering and Minkowski, much interest has been taken in the relationship of the pancreas to diabetes. Extirpation of the pancreas in dogs is followed within twenty-four

hours by glycosuria, reaching its maximum on the third day, when it amounts to 8 or 10 per cent. on a carbohydrate-free diet. This is associated with excess of sugar in the blood, and the presence of acetone in the urine. The constancy of the ratio of the carbon to the nitrogen excreted (2·8 to 1) is best explained by supposing that protein is the source of this sugar. Though glycosuria does not follow an ordinary diet if $\frac{1}{8}$ to $\frac{1}{12}$ of the gland is left, it does if any excess of carbohydrate be given. This portion of the gland can still exert its control even if its connection with the duodenum be severed.

These facts are usually explained by saying that the pancreas furnishes an internal secretion to the blood or lymph which is necessary for normal metabolism; either—

(*a*) A glycolytic ferment which breaks down the sugar into some simpler form in which the tissues can use it, or—

(*b*) Something which is necessary to the assimilation of sugar by the tissues.

Pavy suggested that this was an amboceptor, which, by linking the small molecules of sugar on to larger molecules, such as protein, prevented their escape in the urine. The most definite experimental results are those of Starling and Knowlton (*Lancet*, 1912, vol. ii., p. 812), who found that, while each gramme of the normal dog's heart consumes about 4 milligrammes of sugar each hour, after excision of the pancreas the heart consumes hardly any sugar at all. The addition

of pancreatic extract to the perfused blood increased the consumption of sugar. They concluded from this and their various control experiments that the tissues and the heart contain some substance essential to the utilization of sugar by the tissues, which is gradually used up and has to be replaced. This substance is apparently supplied by the internal secretion of the pancreas. No such secretion has ever been isolated, however, and we are merely postulating its existence as the simplest explanation of the facts.

Another possibility presents itself. In diabetes it might be that it is not so much the pancreas which is at fault as that the stimulant to its action is missing.

Secretin might be the stimulant to the internal as well as the external secretion. This is the basis of the theory of intestinal glycosuria. Evans showed, however, that after complete removal of the pancreas prosecretin rapidly disappears from the intestinal wall. The loss of secretin in pancreatic diabetes is therefore merely a result, and not a cause, of the failure of the pancreas. Considering that secretin is not absorbed from the lumen of the intestine, it could not be expected to relieve symptoms due to loss of either the external or internal secretion of the pancreas when given by the mouth, and there is a general consensus of opinion that it does not. Spriggs also found that intravenous injections of secretin were of no avail in diabetes.

The causation of glycosuria will be considered more fully in a later chapter.

The Meaning of the 'Cell-Islets.'

The 'cell-islets' described by Langerhans in the pancreas have been regarded by many as the source of this internal secretion. These ovoid groups of shrunken, poorly-staining cells are apparently developed from the secreting alveoli, with which in reptiles they remain continuous. In man, delayed development, in consequence of congenital syphilis, for instance, may lead to persistence of this embryonic continuity. Normally they contain no ducts, and are supplied with wide tortuous capillaries or 'sinusoids.' In man they are scattered irregularly through the gland, though in some animals, such as the cat, they are constantly in the centre of the lobe. Rennie found very large islets in the bony fishes, including in some a principal islet, separated from the rest of the organ, visible to the naked eye, and capable of dissection.

Opie is a strong supporter of the view that injury to these islets is responsible for the disturbance of carbohydrate metabolism. He claims that the more selective the influence of a lesion is upon the islets, the more likely is it to cause glycosuria. Thus interstitial pancreatitis may be interlobular or interacinar; the latter soon affects the islets which lie deep within the lobules, whereas the former has to be far advanced for the islets to become involved. Corresponding to this, he finds the interacinar form is much more frequently associated with glycosuria than the inter-

lobular. Hyaline degeneration, too, which he describes as particularly liable to affect the islets, he believes to be specially apt to produce glycosuria.

On the other hand, Dale has advanced strong reasons for believing that these islets do not represent fixed and permanent structures in the gland, but are being continuously formed from secreting alveoli. By injection of secretin he has been able to imitate the normal stimulation of the pancreas, and yet to carry it to a pitch of exhaustion of which previous methods would not allow. As a result he finds islets of such abundance and of such a size as are never seen in any part of a resting gland. Moreover, they show signs of active formation. Apart from large areas of definite islet tissue, a considerable proportion of the remaining alveoli show partial change, some cells having lost their normal staining properties, and having become assimilated to centro-acinary cells. There is frequently apparent continuity of the islets with the epithelium of the smaller ductules. The proportion of islet tissue to secreting tissue is also increased by prolonged fasting —*i.e.*, the disappearance of the stored material, whether by discharge from the duct or by absorption into blood or lymph when nutrition fails, is attended by increased formation of islet tissue.

He concludes that the islets are not independent structures, but are formed by certain definite changes in the arrangement and properties of ordinary secreting cells, bringing about a reversion to embryonic type

A study of Dale's microphotographs is certainly very suggestive, showing as they do all transitional forms between alveoli and islets. Indeed, ordinary cell-islets, when prepared by Heidenhain's method, produce a distinct impression of badly-staining, shrunken alveoli that have lost their normal arrangement. It is, however, rather difficult to understand why they should be found in a different position in different animals, if produced in all alike by breaking down of ordinary alveoli.

After all, the nature of the islets does not really settle the question of internal secretion. If this exists, it does not necessarily require special cells to elaborate it. In the liver, we do not find certain bile-producing cells and other glycogenic cells, but all the cells seem equally concerned in both the internal and external secretions of the glands. Noel Paton points out that, while the cell-islets are well developed in the duck, the pancreas plays no important part in regulating the metabolism of sugar, for excision of the pancreas does not cause glycosuria in that animal. This throws doubt on the hypothesis that their function even in mammals is to regulate carbohydrate metabolism. They have frequently been found degenerated when no glycosuria has occurred. Though cell-islets are increased by injections of secretin, such treatment has not alleviated diabetes. Rennie and Fraser fed diabetics with the principal islets of fishes, but the results were inconclusive.

The Manifestations of Pancreatic Disease.

Disease of the pancreas is still considered to be rare, but, in view of its multifarious duties, it would be strange were this really true. Gross lesions may be rare, but inflammatory changes are not uncommon. 'Catarrhal jaundice' is often pancreatic in origin, and it is probable that in many cases of intractable dyspepsia the pancreas is at fault.

Three main factors tend to obscure the diagnosis of pancreatic disease:

1. 'Disease of the organ is seldom uncomplicated, but is usually consequent on changes in the duodenum, liver, or bile-passages' (Opie); and when not the result of such changes, it may be the cause of them.

2. The digestive work of the pancreas can be largely carried out by other secretions. Digestion of fat has been thought to be an exception to this statement. But even under aseptic conditions the gastric juice is capable of splitting 50 to 60 per cent. of the fat of the food into fatty acid and glycerine. Moreover, fat-splitting can also be accomplished by intestinal bacteria. This accounts for Abelmann's observation that, after excision of the pancreas in dogs, 53 per cent. of the fat of milk is still digested, and for Hédon's and Ville's, who found that 50 per cent. of fat was digested after the pancreatic juice was prevented from reaching the intestine.

Another source of fallacy is that occlusion of the

main pancreatic duct may be partially compensated for by the duct of Santorini.

On the other hand, occlusion of the bile-duct, or tuberculosis of the alimentary tract, may result in excess of fat in the stools without pancreatic disease.

3. Pancreatic disease is only one of many causes of glycosuria, and lesions which only affect part of the gland may not be accompanied by glycosuria at all.

Bearing these sources of error in mind, we may now consider—

The Signs of Pancreatic Inadequacy.

1. *Defective External Secretion* as indicated by—

(*a*) *Failure of Tryptic Digestion.*—Unaltered muscle nuclei may be found in the fæces after a meat meal.

To aid the detection of these nuclei, the muscle fibres may be enclosed in small silk or muslin bags. Schmidt and Kashiwado employ capsules containing lycopodium and stained muscle nuclei, the large size of the lycopodium grains acting as a guide to the coloured nuclei. Even with this aid it cannot be said that the finding of the nuclei is an easy matter. Sahli's method of enclosing drugs in gelatin capsules hardened by formalin cannot be recommended. He claims that if the pancreatic secretion is inadequate the drugs will not be set free, and therefore not found in the urine or saliva. But if the capsules are not hardened enough, they may be digested in the stomach; while if they are hardened too much, as is more commonly the case,

no reaction is obtained even though the pancreas is healthy, because the capsule now resists tryptic digestion also.

It is claimed that trypsin can be demonstrated in normal stools by placing a small quantity of fæces on a gelatin plate, when a small area of digestion will result. With absence of the pancreatic secretion this would not occur.

(*b*) *Failure of Starch Digestion.*—Though ptyalin can digest boiled starch, amylopsin alone can digest unboiled starch grains. Abelmann found 20 to 40 per cent. of the starch in the fæces after experimental excision of the pancreas. Chronic pancreatitis may cause oxaluria from intestinal fermentation of carbohydrates (Cammidge and Robson).

(*c*) *Failure of Fat Digestion.*—This may result in true steatorrhœa, or in the presence of fat droplets, fatty acid crystals, or soap in the fæces in such amounts as can only be detected by the microscope. But a quantitative estimation is necessary to determine the excess of fat satisfactorily. In normal fæces the saponified and unsaponified fats are approximately equal in amount, the total amount of the two being 15 to 25 per cent. of the solid matter. As the pancreas provides for the fat-splitting that must precede saponification, unsaponified fat will be in excess of the saponified if the excess of fat in the stools is due to a pancreatic defect. On the other hand, the bile-salts provide for the absorption of the fat already digested by the pancreatic juice, so that if the excess of fat be due to loss of bile simply,

the saponified fats will be in excess, because they cannot be adequately absorbed.

2. *Defective Internal Secretion as indicated by—*

(*a*) *Diminished Sugar Tolerance.*—Though spontaneous glycosuria may be absent in pancreatic disease, it may often be excited by a carbohydrate diet. Thus, Wille tested a large number of patients with various diseases by administering 70 to 100 grammes of dextrose dissolved in ½ litre of tea or coffee. The urine was passed just before, and was then tested at intervals of two hours. If alimentary glycosuria exists, sugar should be found two hours after a meal. A normal person can take 150 to 200 grammes of dextrose at one time before glycosuria occurs.

Wille found that, of fifteen cases of alimentary glycosuria thus tested, which he was able to follow to necropsy, ten had grave lesions of the pancreas. Though alimentary glycosuria may occur in other conditions, such as exophthalmic goitre and alcoholism, it remains a sign of considerable value when in conjunction with other evidence of pancreatic insufficiency. A negative result does not exclude pancreatic disease, for as long as sufficient tissue remains to form the internal secretion this symptom will be lacking. Our treatment must be directed towards removing the cause before glycosuria has occurred. It should be regarded as a late symptom, and one that makes the prognosis more serious.

(*b*) *Adrenalin Eye Test.*—When adrenalin is instilled into an excised eye, the pupil dilates. But normally

this mydriasis does not occur with the eye *in situ*. If, however, the pancreas is inadequate, the pupil will dilate in from twenty minutes to one hour after one drop of the liquor adrenalin hydrochlor. is dropped into the eye, and another drop five minutes later. Loewi explained this as due to an upset in the normal antagonistic action of the suprarenals and the pancreas. If the latter is in defect, the former will be relatively in excess, and the addition of adrenalin will enable it to assert itself, so that dilatation of the pupil is no longer inhibited. My experience of the test is that it is, if anything, too sensitive. The primary disease may be in the liver, for example, and the pancreas merely secondarily involved, yet the reaction is positive. I had an example of this in a primary carcinoma of the liver with a slight secondary pancreatitis. Again, if there is thyroid excess, the reaction may be positive, although there is no disease of the pancreas, for there is also an antagonism between the internal secretions of the thyroid and pancreas.

3. *Signs of Pancreatic Disintegration.*—

(*a*) *Increase in Urinary Diastase.*—There is normally a diastatic ferment in the urine, and it is found to be much increased in pancreatic diseases. It is also increased after any manipulation of the pancreas. Apparently this is due to escape of amylopsin from the gland into the blood-stream, and may therefore be classed as a sign of pancreatic disintegration. Wohlgemuth originally introduced the quantitative measurement of this ferment as a test of renal efficiency, but

it has been found of more value as a sign of pancreatic disease. Indeed, at St. Bartholomew's Hospital we have come to regard it as one of the best of the pancreatic tests. Ten test-tubes are taken containing amounts of urine varying from 0·6 to 0·06 c.c. The smaller quantities are measured by using a 1 in 10 dilution with NaCl. The amount of fluid is made up to 1 c.c. by the addition of 1 per cent. NaCl. Two c.c. of a 0·1 per cent. starch solution is added to each tube, and the contents carefully shaken. The tubes are kept in a water-bath at 38° C. for half an hour, and then placed in cold water for two or three minutes to stop the ferment action. To each tube is added 1 drop of a 1 in 50 normal solution of iodine in distilled water, and the first tube in which a blue colour appears is noted. Here there must be some undigested starch, while in the one below in the series the digestion is complete. Thus, if the tube containing 0·1 c.c. of urine is the first to show blue, in the one containing 0·2 c.c. digestion is complete—*i.e.*, 0·2 c.c. will digest 2 c.c. of 0·1 per cent. starch solution in half an hour, and 1 c.c. will therefore digest 10 c.c. We accordingly say that this urine contains 10 units. The normal figures average 10 to 20 units, but may range between 6·6 and 33·3 units. In diseases of the pancreas, on the other hand, there may be 200 to 300 units, and even higher values have been obtained. In ordinary diabetes, on the other hand, the figures are usually subnormal. It must be admitted that this is an argument against ordinary diabetes being connected

with disease of the pancreas. (For further details see Corbett, *Quarterly Journal of Medicine*, 1913, vol. vi., p. 351.)

(*b*) *Cammidge's Pancreatic Reaction* would fall under this head, as the source of the pentose in the urine is thought to be the pancreatic cells breaking down as the result of inflammatory change. But, as already stated, most observers have concluded against the value of this test.

Other evidences of pancreatic disease may be obtained from—

4. *Pressure Symptoms.*—These may be referred to—

(*a*) *The Common Bile-Duct, producing Jaundice.*—In new growth of the pancreas the obstruction may be complete, while in gall-stones it is more likely to be incomplete, so that stercobilin can be extracted from the fæces by acid alcohol or amyl alcohol, even though they appear quite clay-coloured. The extract gives a band in the blue on spectroscopic examination, and a green fluorescence with zinc chloride and ammonia if there is any stercobilin present.

(*b*) *The Portal Vein, producing Symptoms of Portal Obstruction.*—This is very uncommon.

5. *Nervous Symptoms, from Irritation of the Solar Plexus.*—In acute pancreatic diseases, such as hæmorrhage, the pain is very severe, the patient feeling as if he were gripped in a vice. Vomiting, meteorism, and collapse follow. In subacute cases there may be periodic seizures of pain and vomiting, like the gastric crises of tabes.

We may say that if the adrenalin eye test and the diastase test are negative, it is seldom worth while to undertake more elaborate investigations. If there are fatty stools without jaundice, and the excess of fat is in the saponified form, it is very suggestive of pancreatic disease. If there are also muscle nuclei in the stools, it strengthens the diagnosis. If all these symptoms are present in addition to glycosuria, the diagnosis is certain.

General Principles of Treatment in Pancreatic Disease.

Certain considerations govern the treatment of pancreatic diseases in general, which may be discussed here without describing the treatment of particular diseases of the organ.

1. *Dietetic Treatment.*—Pancreatic juice contains ferments which are capable of acting on all foodstuffs, and the only one able to split fat to any extent, the lipolytic power of gastric juice not being of much practical importance. It therefore follows that when the pancreas is diseased, fats are badly borne, for not only are they wasted, excess of unsaponified fat appearing in the stools, but by coating over the proteins they hinder their absorption and increase their putrefaction. Proteins are digested by pepsin, and can therefore be given so long as a form is chosen in which they can be acted upon rapidly in the stomach, such as minced meat. Certain proteins like caseinogen are

also digested by the erepsin of the succus entericus, and can therefore be used—*e.g.*, plasmon or protene, but not egg-albumen. In addition, the relatively large amount of sulphur contained in eggs renders them very prone to putrefactive changes. Gelatin, on the other hand, does not contain aromatic bodies, and so is not so liable to these changes, and can replace proteins to a limited extent.

For the digestion of starch we have to rely upon the ptyalin of the saliva; and to take advantage of this, starchy foods should not be given in a soft form, such as ground rice, but in a dry, crisp form, like toast, biscuit, or rusk, which, requiring thorough mastication and insalivation, reaches the duodenum already largely digested. Sugars like glucose can be absorbed without further digestion, while cane sugar, maltose, and lactose can be digested by the succus entericus. But their use in pancreatic diseases is, unfortunately, limited by the diminished sugar tolerance found in many pancreatic lesions. The limit of carbohydrate tolerance should therefore be determined in the way described under Diabetes. If glycosuria is already present, the ordinary dietetic rules for that condition apply.

2. *Regulation of the Pancreatic Secretion.*—The acid of the gastric juice is the great stimulant to both the external and internal secretion of the pancreas. Accordingly, if it is deficient, it should be reinforced by the administration of dilute hydrochloric acid, or better, 15-grain tablets of betain chloride (acidol),

freshly dissolved in water after meals. This liberates nascent hydrochloric acid slowly in the stomach. On the other hand, hyperchlorhydria overstimulates and finally exhausts the pancreas, thus helping to set up chronic pancreatitis. It should therefore be corrected by alkalis, including magnesia, after meals.

3. *Supply of Deficient Ferments.*—This presents difficulties. The simplest method would be to pancreatize the food before administration, but this is liable to impart a bitter, disagreeable flavour. If ferments are given to act when the duodenum is reached, they will be destroyed in the stomach unless enclosed in capsules capable of resisting gastric digestion, and then we can feel little certainty that they will be set free in the duodenum. Keratin-coated capsules are supposed to be the best. Capsules of gelatin toughened in formalin are apt to escape undigested even in the healthy subject. Taka-diastase has been given before meals for the digestion of carbohydrates. One or more $\frac{1}{4}$-grain tablets of Pankreon with meals may be given a trial. Holadin is said to contain all the external and internal secretions of the gland. As it has been repeatedly demonstrated that the internal secretion of the pancreas cannot be absorbed by the intestinal mucosa, the advantage of its addition is problematical. It is given in capsules. Stockton states that he has been unable to convince himself that any such ferments produce any improvement in the general condition of the patient or in the stools. He adds that many preparations on the market are practically inert, and many

combinations are self-destructive, provided they are made as described.

4. *Disinfection of the Pancreatic Ducts.*—Two drugs are known to be excreted by the pancreatic ducts, as well as by other channels. These are helmitol and aspirin, both of them disinfectant in action. Routine employment of them in doses of 5 to 10 grains three times a day is therefore a rational procedure, and should be given a thorough trial. But perhaps the most efficient means of ridding the pancreatic ducts of infection is to drain them by a cholecystostomy, which, if indicated, should not be too long delayed.

5. *Diminution of Intestinal Putrefaction, resulting from Diminution or Absence of the Pancreatic Juice.*—The dietetic factors in this have already been considered, and the question of intestinal antiseptics is discussed in a later chapter.

Any chronic disease of the pancreas, accompanied by insufficiency of its secretion, will call for some or all of these methods of treatment.

CHAPTER V

URIC ACID AND THE PURIN BODIES

We can only form an opinion as to the part that uric acid and allied substances play in disease by studying their normal behaviour in the body. Uric acid is a subject which has a peculiar fascination for the lay mind, and our patients often seek or wish to impart information concerning it. Again there is something about uric acid, as there is about alcohol, which seems to turn the mildest-mannered man into a heated partisan. The widest differences of opinion prevail; thus, while Haig regards it as the cause of nearly all the ills that human flesh is heir to, Luff looks upon it as a harmless by-product of metabolism. Between these two views there is plenty of room for the exercise of private judgment.

What are Purin Bodies? — Fischer gave the general name of purins to bodies containing the nucleus C_5N_4, which will yield two urea molecules on oxidation. Only twelve different purins are known to exist in nature, though 146 have been

prepared in the laboratory. The most important ones are—

Oxy-purins	Hypoxanthin ..	$C_5N_4H_4O$
	Xanthin	$C_5N_4H_4O_2$
	Uric acid	$C_5N_4H_4O_3$
Amino-purins	Adenin	$C_5N_4H_4NH$
	Guanin	$C_5N_4H_4O.NH$
Methyl-purins	Theobromine ..	$C_5N_4H_2(CH_3)_2O_2$
	Caffein and thein ..	$C_5N_4H(CH_3)_3O_2$

The source of urinary purins is partly from the food (exogenous), and partly from the tissues (endogenous).

1. *Exogenous Purins.*—We take these substances in as—

(*a*) Methyl-purins in tea, coffee, and cocoa.

(*b*) Free purins, such as xanthin and hypoxanthin, in meat-extracts.

(*c*) Bound purins. Nuclei yield purins in their decomposition. The more cells a food contains the more nuclei it has, and therefore the more purins it yields. Accordingly, cellular organs, such as liver and sweetbread, are a great source of purin intake.

In the following table, taken from Walker Hall, the bound and free purins are estimated together, the foods having been weighed just as they are used in the household:

	Purins in Grains per Pound.
Fish :	
Cod	4·07
Salmon	8·15
Meat :	
Mutton	6·75
Beef	7·96 to 14·45

	Purins in Grains per Pound.
Meat :	
Chicken	9·06
Liver	19·26
Sweetbread	70·43
Eggs and cheese	almost 0
Vegetables :	
White bread, rice, cabbage, cauliflower, lettuce	0
Potatoes	0·14
Asparagus	1·5
Peas	2·54
Oatmeal	3·46
Beans	4·16

	Purins in Grains per Pint.
Beverages :	
Wines	0
Milk	0·0014
Beer	1·09 to 1·27

	Methyl-purins. Grains per Teacup.
Tea, China	0·75
Tea, Ceylon	1·21
Coffee	1·7

It will be seen from this table that the practice of distinguishing between red and white meats in dieting a gouty patient is apparently unsound if it is regarded as a method of regulating his purin intake. To cut a patient off mutton and give him chicken and sweetbread hardly achieves the object that is presumably in view.

Adler claims, however, that white meats lose their extractives more readily on cooking than do red; thus, veal loses four-fifths of its extractives, while beef loses

hardly any. Incidentally, the result of this must be that veal broth is laden with purins.

2. *Endogenous Purins.*—Even on a purin-free diet the urine contains purin bodies, so that some must come from the body tissues. Though the form of the purins may vary, the total remains fairly constant for the same person living under the same conditions, and amounts to about 0·2 gramme of purin nitrogen daily. An important source seems to be the leucocytes and the muscles. It has usually been assumed that it is the disintegration of the nuclei that provides the purin. But Plimmer believes that it is not when the leucocytes are being destroyed, but while they are active, that the output of uric acid is high. Thus, in pneumonia the increased output of uric acid runs parallel with the leucocytosis, and after the crisis, although there is a large destruction of leucocytes, this increased secretion of uric acid comes to an end. This is disputed by other observers. As for the muscles, during exercise there is merely an alteration in the proportions of the purin bodies. There is less uric acid and more xanthin and hypoxanthin. As the latter bodies are less oxidized than uric acid, it is probable that they replace it during exercise, because of the demands made elsewhere for oxygen. But after exercise, especially of an unaccustomed form, there is a considerable rise in the uric acid excretion. This might be explained by the washing out of retained uric acid by the more vigorous circulation induced, especially as repetition of the same exercise does not have the same effect. But Kenna-

way has found, so long as the form of exercise is varied, the increased output occurs. This, he considers, points to a heightened activity of the processes that form uric acid rather than to the sweeping out of it from the body. It is certain that the endogenous purins do not come from nucleo-proteins alone, for Garratt has shown that in fevers the rise in uric acid output is not accompanied by an increased output of phosphoric acid, which is a constant constituent of nucleo-proteins. Graham and Panton conclude that purins are synthesized from proteins and carbohydrates, for a diminished intake of either leads to diminished formation of endogenous purins. The nucleins of the food do not appear to be utilized for this purpose. This accords with the clinical experience that excess of carbohydrates are bad for gouty subjects.

The Effect of Ingestion of Purin Bodies.—'If we believe popular medical, to say nothing of lay, opinion, uric acid is a virulent, all-pervading poison,' says W. G. Smith, 'yet it is a normal constituent of our bodies, and . . . is regularly found in the blood of birds.' Now, as Gore points out, 'uric acid can be no exception to the general law that a substance acts as a poison in direct proportion to the amount of it present in the circulating fluid.' We know that in leukæmia as much as 5 grammes of uric acid may be excreted in a day from the leucocytes. If uric acid is a direct poison, why does it not produce symptoms in leukæmia similar to those of 'uric acid diseases'?

Walker Hall thinks that, although purins have not

the powerful toxic properties usually ascribed to them, they are not entirely harmless. He tried the effect of taking considerable amounts while fasting, with the following results: 1 gramme of *caffein* caused a sensation of warmth in the abdomen and over the whole surface of the body. There was intense headache and some muscular twitching. On a second occasion a similar dose caused fulness in the head, a loss of muscular sense, and confusion of ideas. Half a gramme of *hypoxanthin* caused a slight fulness in the head, and a feeling of stiffness over the whole body. With *uric acid* a dose of $\frac{1}{2}$ gramme caused distinct headache and confused ideas, with a sensation of warmth in the abdomen. On the second occasion the same dose caused slight headache, with sensory disturbances in the abdomen. On the third occasion a dose of 1 gramme caused no symptoms at all. Tolerance was therefore quickly established to doses of even 1 gramme, taken while fasting. This perhaps also explains the intolerance to purin-containing foods sometimes acquired by those who have adopted a purin-free diet.

Repeated injections of hypoxanthin into rabbits caused a cellular reaction in the liver and kidneys, and slow growth of the animal, but no rise of vascular tension was detected.

History of Purins after Ingestion.—After excision of a dog's kidneys, no uric acid or other purins can be found in the blood even on a diet rich in purins. This seems fatal to the hypothesis of 'retention' of uric acid, to which so many diseases have been referred.

Something must be able to destroy purins, probably intracellular ferments in the liver, since extracts of that organ cause uricolysis both *in vitro* and *in vivo;* while if the liver be excluded from the circulation, the uric acid in the blood and urine is increased.

Such food purins as appear in the urine have escaped by the kidneys before they could be destroyed in the liver. The amount has been stated to be from a quarter to a half of that ingested. In Plimmer's experiments, however, only one-tenth of the ingested purins, taken as herring roe, could be recovered from the urine. Kennaway found that while xanthin and hypoxanthin are proportionately more abundant with a copious flow of urine, the more oxidized uric acid is relatively more abundant in concentrated urine. In other words, the more rapidly excretion is going on, the more purins are removed before they can be oxidized. The final stage of the oxidation in the liver gives rise to urea. Hypoxanthin, xanthin, uric acid, urea, then represent successive steps in the oxidation of the purins, and the proportion in which they appear in the urine depends on the activity of the liver as compared with the rate of urinary excretion. An example of this is seen on comparing the urine in a case of failing heart with that of parenchymatous nephritis. In both the urine is concentrated, but in the former it is loaded with urates, while in the latter the urates are diminished, because, the excretory cells being damaged, and not merely congested, the liver can destroy purins more completely before the kidney can excrete them.

Plimmer found one condition in which ingestion of purins led to a considerable increase in their excretion. After giving Liebig's extract of meat, there was an increased excretion of uric acid equal to more than half the purins in it. This differed so widely from his other results that he made further investigations, and found that the meat-extract produced leucocytosis, which may be accompanied by increased uric acid formation. He thinks that the leucocytosis was necessary to remove toxic substances contained in the meat-extract. If this be so, it raises doubts as to the wisdom of treating infective conditions by the artificial production of leucocytosis by nuclein injections, etc. Indeed, it has never been clear that such procedures do more than evoke enough leucocytosis to deal with the injected material.

Increased excretion of purins, then, may be due to—

1. An excessive intake of purins. But as long as the body is healthy, 90 per cent. of the purins ingested may be destroyed.

2. Defective action of the liver, which fails to break down the purins in the way it should.

3. Anything causing leucocytosis.

4. Unaccustomed muscular exercise.

The upholders of the uric acid theory of disease assume that the body can deal with its endogenous purins, but is poisoned by ingested purins. There is little in the history of purin metabolism to support this view. We have seen that there may be a great increase in uric acid production without gouty symp-

toms, and that a healthy liver has a great power of destroying purins. Moreover, a vigorous reaction of the body to infection is marked by an increased production of purins, and it is probable that the increased output of purins after giving meat-extract is simply due to the leucocytic reaction it induces. Leathes and others have shown that the quantity of uric acid excreted is greatest in the early waking hours of the day, and least during the night. In other words, its excretion runs parallel with bodily activity.

Purins and Gout.—We must enlarge our conception of the work that the liver has to do. It not only forms urea, but it does so, in part at least, by destroying uric acid and allied bodies, by a number of specific ferments; and we may perhaps look forward to the day when, as Hopkins says, we shall not speak of a patient possessing a diathesis, but of his lacking some one of these ferments.

I believe we may look upon a person who is readily poisoned by purins in the same light as those who have cystinuria, alkaptonuria, or pentosuria—*i.e.*, they all lack a link in the chain of protein katabolism, so that intermediate products appear in the urine instead of the usual end-products. The curious point, to my mind, about the man who cannot metabolize purins is his fixed belief that the rest of mankind suffers from a similar incapacity. Hence the elevation of the purin-free diet to the dignity of a cult.

If food purins lead either to a uratic deposit in the tissue or to a high purin output, it is a sign of hepatic

insufficiency rather than the cause of disease. Amid all the confusion that reigns on the pathology of gout we can hold to the two definite facts established by Sir Alfred Garrod: in gout there is an excess of uric acid in the blood, and during the paroxysm a diminished output of uric acid in the urine. To this we may add that there is a retardation in the excretion of exogenous purins. The whole reveals a deficiency in the capacity of the body to katabolize purins. Mere retention of purins will not *cause* gout. Uric acid can always be demonstrated in normal blood or lymph; in gout and lead-poisoning the amount is increased, though not so much as was formerly thought. The blood is capable of carrying much more sodium urate in solution than it is usually asked to do. Walker Hall had calculated that the average daily output could be suspended in the quantity of blood passing through the lungs in five minutes, or through the kidneys in twenty minutes. Even after severe muscular exercise or in fever the quantity eliminated is well within the suspension capabilities of the blood stream. He considers that the small purin increase in the blood of a gouty individual cannot be responsible for the deposits in joints and tophi, since there is such a considerable margin of solubility available. Nor does the hypothesis of renal inadequacy provide a satisfactory explanation, since the kidney of diffuse nephritis, which is much more damaged than the gouty kidney, can excrete uric acid at a normal rate. An additional factor must come in, and, as Walker Hall

says: 'Gouty individuals possess some inborn defect or alteration of nuclein metabolism which lowers the resistance of the tissues in certain directions, and so permits a response to irritants which are scarcely appreciated by those whose metabolism does not exhibit this peculiarity.'

It is only reasonable in such cases to diminish the intake of substances which are not necessary as foods, and which tax the liver to metabolize them, and the kidney to excrete them. But this will not satisfy the enthusiasts. Goodhart complains: 'It is diet, diet, diet, all the time for the man who passes uric acid. It is "get the uric acid out of your system," and all will be well. But though you absolutely exclude all uric-acid-forming food, of whatever kind you assume that food to be, you may wither up your patient into a shrivelled, juiceless, prematurely aged being, and there will yet, by some means or other, under favouring conditions, be squeezed out of his tissues enough uric acid to form a large deposit of red crystalline matter in his urine.' This accords with the experimental evidence that checking the ingestion of purins does not prevent their endogenous formation.

This modified conception of the source and history of purin bodies should diminish our ardour in trying to wash uric acid out of the system. 'Much therapy is directed against this necessary result of nuclein metabolism,' but, as a matter of fact, most drugs have an insignificant effect in increasing the elimination of uric acid and its allies.

Water, by producing diuresis, certainly increases the output. It is chemically impossible that *lithium salts* can have any effect in this direction. We know that chemical action is determined both by the mass and the avidity of the various interacting bodies, but also that if in any mixture of acids and bases an insoluble salt can be formed, it will be formed. In face of this, what can be the use of a few grains of lithia introduced into the body to combat an amount of sodium which, in addition to all the advantage of mass reaction, forms the less soluble salt? Lithium is, moreover, distinctly depressing in its action on the spinal cord, motor nerves, and alimentary canal.

Piperazin has been shown by Fawcett and Gordon to have no solvent action even in full doses. *Urotropin* can cause a very slight increase in the purin output.

The action of *alcohol* is complicated. With malt liquors there is an actual intake of purins, while in all cases alcohol leads to diminished solubility of purins.

Minkowski has suggested that *thyminic acid* (an organic acid containing phosphorus) is the substance which holds uric acid in solution in the circulation. Quadriurate of soda has for some time been regarded merely as a mixture. Thyminic acid can hold its own weight of uric acid in solution at 20° C., and 50 per cent. more at body temperature. Although we no longer believe that deposit of biurate of soda explains the whole pathology of gout, and look upon it rather as a symptom, yet we can quite understand that a case of gout would be improved if the deposit could

be prevented. I was therefore anxious to test whether thyminic acid would prevent uratic deposition, but could not obtain the drug. However, Fenner was more fortunate. He employed it in doses of 4 to 8 grains three times a day, with results in both acute and chronic gout which he considered most gratifying. The drug is put up in tablet form under the name of Solurol. But although it has been on the English market since 1905, the number of reported successes remains very small, and its use appears to be making but little headway.

Salicylates can cause a very markedly increased output—sometimes as much as 50 per cent. But it is not a little disturbing to find that this increase will occur even after a purin-free diet has been taken for years. There are three possible explanations:

1. That salicylate washes out retained uric acid. But since the liver rapidly destroys uric acid, retention does not occur, and therefore washing out cannot be effected.

2. That the drug causes increased katabolism of the tissues. But the increase is too great, and no marked loss of weight occurs on administration of salicylates such as this hypothesis would necessitate.

3. That it causes synthetic production of purins. This is not proven, but by a process of exclusion seems the only possible explanation. It would appear ironical if, in their enthusiasm for ' washing out ' uric acid, those to whom it is anathema are merely increasing its production.

Atophan (2. phenylchinolin, 4. carbonic acid,) is another comparatively new phenol derivative which definitely increases the output of uric acid. When it is taken by a healthy individual, the excretion of uric acid even on a purin-free diet rises at once, and then slowly falls, returning to normal by the third or fourth day. When uric acid is injected into a normal man, its excretion is spread over several days, and the total amount injected is not recovered. But if the injection is given during a course of atophan, the excretion of uric acid is completed within twenty-four hours, and the whole amount is recovered. In a gouty individual the same results are obtained (Walker Hall), so that under the influence of atophan the gouty and the healthy renal cell seem to excrete just the same amount of uric acid. Its administration appears to shorten the acute stage of gout, and is accompanied by increased uric acid output. So far as it goes, this might be held to support the retention theory. More probably, however, both retention and constitutional disturbances are due to the same unknown perversion of metabolism, and the drug affects the endogenous formation of purins. Atophan is put up in tablets containing $7\frac{1}{2}$ grains, 4 to 6 of which should be given in the day, broken up in plenty of water. Weintraud, who warmly recommends it, advises full doses of sodium bicarbonate at the same time, such as $\frac{1}{2}$ ounce on the first day, and $1\frac{1}{2}$ drachms on subsequent days. The method is well worth a trial both in acute and chronic gout.

It is obviously contra-indicated in urinary calculus and gravel.

The use of *colchicum* in acute gout is purely empirical, but is undoubtedly often efficacious in the relief of pain. Dixon and Malden found that its active principle—colchicine—excited the nerve endings of plain muscle, and that the number of leucocytes diminished at first, afterwards returning in increased numbers. It is probable that the exciting effect on plain muscle is responsible for the purgative action of colchicine, which may serve to eliminate some gastro-intestinal toxin, while the diminution of leucocytes, by diminishing the endogenous formation of uric acid at this juncture, may perhaps just tide over the metabolic difficulty. The return of the leucocytes in increased numbers would account for the failure of colchicum to exert a prolonged influence.

Prevention of Deposition of Uric Acid in Urine.—Though we can do comparatively little to increase the output of uric acid, we can and ought to check its deposit in the crystalline state in the urine, causing symptoms of stone and gravel. Sir William Roberts showed the importance of high acidity and high percentage in causing this deposit.

Acidity is at its height during the fasting hours, and seldom is a marked feature during digestion, owing to the loss of acid by the gastric juice. It is usually sufficient to give 20 grains of *potassium citrate* night and morning to correct high acidity. There is, however, one precaution which I have not seen mentioned,

but which seems to me important. If uric acid deposit has already occurred in the form of a calculus, rendering the urine alkaline will cause growth of the calculus by accretion of phosphates. I therefore tell the patient to put a piece of red litmus-paper into the morning urine. If it turns blue, the drug must be diminished in amount until this just does not occur. *Fresh fruit*, such as pears, green figs, dates, oranges, and grapes, have been shown by Smith Jerome to have a similar action in checking high acidity. Fresh fruit, however, does not seem to suit the gouty subject with a large formation of endogenous purins.

High percentage of uric acid may be absolute or relative—that is, the total output may be increased or the urine may be concentrated. Both may favour deposition. The former should be regulated by cutting off foods rich in purins, the latter by diluting the urine, Patients do not care to be ordered to drink plain water. *Potash water* is preferable to soda water, because of the relative insolubility of the sodium salts. But, for the reasons I gave when considering the action of lithia, it is the water which is the chief therapeutic agent.

Certain waters, such as those of Contrexéville, have a high repute for washing out uric acid. It has been questioned, however, whether the treatment at Contrexéville does not increase the endogenous formation of uric acid; whether, in short, as Goodhart says, the gravel passed is not manufactured on the premises. But an alkaline mineral water will help to prevent

deposit of gravel both by diluting the urine and by rendering it less acid.

Gee pointed out the extraordinary effect of *whey* in preventing uric acid deposits, and I have repeatedly confirmed this. I do not know whether the effect is due to its action as a diuretic, but there is no doubt as to the fact. A breakfastcupful should be given twice or thrice a day.

To sum up, uric acid is merely one, and one of the less toxic purin bodies. The purins come partly from the foods and partly from the tissues. The food purins are largely destroyed by the liver in health, giving rise to urea. The tissue purins are increased by leucocytosis and muscular activity. Though we can control the intake of food purins, we have very little control over the tissue purins. For the ordinary individual, purins have hardly any toxic action. The gouty subject seems unable to metabolize his purins properly, and his kidneys excrete them too slowly. The inadequate metabolism leads to toxic symptoms, and the inadequate excretion to uratic deposit. It is still unknown what causes this inadequacy. Most of the drugs supposed to wash out uric acid from the system are incapable of doing so. Atophan and salicylates will definitely increase the excretion of uric acid, but it is doubtful whether they do not do so in part, at any rate, by increasing its production. It is reasonable to diminish the purin intake in individuals whose power of metabolizing purins is defective, but probably in many cases much of the good done is simply

due to reducing the quantity of food eaten by making it monotonous. Deposit of uric acid in the urinary tract can be diminished or prevented by diluting the urine and rendering it less acid.

Estimation of the Urinary Purins.—The only method suitable for clinical work is Walker Hall's purinometer. The apparatus can be obtained from Messrs. Gallenkamp for 25s. It is easy to work, but gives only a very rough approximation. It has not proved of much general utility.

CHAPTER VI

OXALURIA, PHOSPHATURIA, AND URINARY CALCULI

Oxalate crystals, phosphatic deposits, and albumen may each occur in the urine under varying conditions, in which they may have a widely different significance. Physiological considerations may help us rightly to appraise these, and point to a line of rational treatment.

The Basis of Urinary Calculi.

Urinary calculi are mixtures of crystalloids and colloids. This fact seems to explain their comparative insolubility, since the colloidal precipitate, which forms an essential part, is 'irreversible'—*i.e.*, does not redissolve on being placed in non-saturated solutions. The ordinary colloids in the urine, such as urochrome and mucin, are reversible, but, according to Schade, in certain pathological, and especially inflammatory conditions, fibrinogen or fibrin, typical irreversible colloids appear. For him, then, an inflammatory reaction is a necessary precursor of a calculus.

Benjamen Moore (*British Medical Journal*, 1911,

i., p. 737), maintains that the discrepancy between the expected and actual solubility of calculi is due to a misconception as to their composition. This has generally been assumed from their appearance or from a partial and qualitative examination only. In this way the tradition has grown up that calculi are most commonly composed in the main of uric acid and urates. The striking murexide reaction is easily obtained if there be present only a small quantity of these substances. But complete qualitative examination of a series of twenty-four calculi removed by operation showed calcium oxalate to be the most frequent constituent of their centres. There were only two exceptions to this—namely, two stones, each removed from the bladder, which were almost purely uratic. This marked difference suggested to him that they were of an entirely independent origin, and had not been formed in the kidney at all. The comparative failure of the medical treatment of renal calculi he considers due to its being directed towards dissolving uric acid by alkalies, which could have no beneficial action on calcium oxalate crystals.

It may be objected that twenty-four analyses are too few on which to base such important conclusions. They form, however, another useful warning against the tendency, so common in medicine, towards unquestioning acceptance of traditional statements, which are copied from one textbook into another. He goes on to urge that it is of little consequence whether a degenerated kidney cell or micro-organism formed

the nucleus around which a renal calculus grows, or whether it starts spontaneously, since it is only a certain type of disordered metabolism producing certain insoluble salts of calcium which can keep it growing. This disordered metabolism he considers to be due to defective oxidation, and gives as other examples of the process the calcification of cartilage and arteries in later life and the calcareous deposits in tuberculous foci, which are non-vascular. But he goes too far in assuming a special relation between calcium and defective oxidation. The deposit of calcium salts tends to occur even in dead matter. Bodies buried in damp soil show it. The structural change occurs first, the deposit of calcium follows.

He lays curiously little stress on the fact that oxalates were the most abundant of the calcium salts in the majority of his cases, regarding this as merely due to their greater insolubility. The treatment he suggests is to diminish the intake of calcium salts by forbidding milk, things made with milk, wholemeal bread and oatmeal. But the conditions leading to an increased excretion of oxalates are also worthy of consideration, since they probably play as important a part in the formation of calculi as the base with which they are combined.

Oxaluria.

The urine contains substances which have been introduced with the food (exogenous) and substances which have been formed within the body (endogenous).

The origin of oxalates from the food is clear; their formation within the body is not easily proved.

Small quantities of oxalates are normally present, but they only have any clinical significance when they are deposited as calcium oxalate in envelope, or, less commonly, dumb-bell crystals.

Sources of Urinary Oxalates—(*a*) *Direct Ingestion of Oxalates in the Food.*—Rhubarb (which contains 0·24 per cent. of oxalic acid), spinach (0·32 per cent.), sorrel (0·36 per cent.), and strawberries, in my experience, are most prone to produce oxaluria in sufficient amount to cause symptoms. But many other articles of diet contain oxalates—*e.g.*, figs, potatoes, beetroot, French beans, tomatoes, plums, tea, coffee, and cocoa.

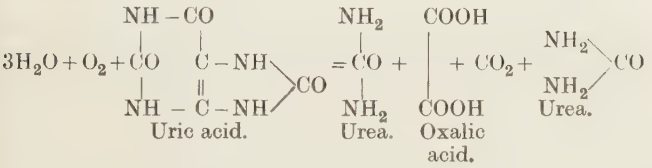
On the other hand, peas, asparagus, mushrooms, onions, lettuce, rice, cauliflower, pears, peaches, grapes, melons, wheat, and oats contain little or no oxalates.

Baldwin's *oxalate-free diet* is composed of meat, milk, eggs, sugar, butter, wheat - meal, rice, and biscuits.

The greater part of the oxalates in the food are in the form of the insoluble calcium oxalate. This can hardly be absorbed as such, but is decomposed by the acid of the gastric juice, which accordingly seems to influence the absorption of alimentary oxalates. Thus, if there is no hydrochloric acid in the gastric juice, there may be no oxalates in the urine, even if spinach be eaten; but on giving hydrochloric acid by the mouth oxalates will appear. Similarly, we may reduce these alimentary oxalates by giving alkalies.

(*b*) *From Gastric Fermentation.*—It is curious that oxalates will appear under precisely opposite conditions—when there is no hydrochloric acid. But to produce them then, abundant fermentation of sugar must be going on in the stomach, producing oxalic acid. As the oxalates are formed in the gastric contents, this amounts to ingestion as the source of the oxaluria. Thus Baldwin produced oxaluria in dogs by feeding on meat and excess of dextrose. A mucous gastritis with absence of free hydrochloric acid resulted, and oxalic acid was found in the gastric contents. The organic acid here provided for its own absorption. As already pointed out, oxaluria may similarly result from chronic pancreatitis.

(*c*) *Endogenous Formation.*—In the laboratory decomposition of uric acid results in the formation of oxalic acid.



A similar change has been assumed to occur in the body. Uric acid is extensively decomposed in the liver. If uric acid is perfused through an excised liver, oxalic acid is formed. If the metabolism of the liver is incomplete, it is easy to suppose the central carbon chain of the uric acid is not completely oxidized, when oxaluria would result.

However, several observers (Dunlop, Baldwin,

Rendle Short) have been unable to find any oxalates in the urine on a milk diet, while others have found traces. We may conclude that endogenous formation does not occur in sufficient quantity to produce a deposit of oxalates which is usually the result either of ingestion of food rich in oxalates or of fermentation in the stomach or duodenum, especially with excess of carbohydrate diet.

The body has considerable powers of dealing with oxalic acid. Esbach took as much as 6 grammes without inconvenience, and though it is almost certain that not all of this could have been absorbed, 0·181 gramme was found in the urine. Minkowski believes that, when once absorbed, oxalic acid does not undergo further oxidation. Maguire thinks that the unexcreted remainder in Esbach's experiment must have been deposited as calcium oxalate in the tissues.

Symptoms—(*a*) *Urinary Irritation.*—Most of the cases only show this. Such cases are common in the strawberry season, especially if the weather be very hot, so that the urine is also very concentrated. I would suggest that there are several factors at work here. Strawberries contain oxalates, cream tends to dyspepsia, and the sugar by its fermentation produces more oxalates.

Micturition becomes painful, and is followed by prolonged smarting. Hæmaturia is not infrequent. Envelope crystals are found abundantly in the urine. I know men in whom such symptoms occur every summer, and one man in whom they occur every time he eats rhubarb.

Albuminuria is often associated with oxaluria, probably from mechanical irritation of the kidney by the calcium oxalate crystals. That actual hæmaturia occurs in the severer cases supports this idea.

(*b*) *Oxalate calculi* may form; they are hard mulberry-stones, usually mixed with uric acid.

(*c*) *Remoter Symptoms.*—It follows, from what I have said, that fermentative dyspepsia will lead to oxaluria. The so-called 'remoter symptoms' and the oxaluria must be referred to a common cause. We must not regard the oxaluria as causing them. The nervous symptoms do not resemble those seen in oxalic acid poisoning at all.

Such symptoms often occur in crises. These crises are sometimes precipitated by worry or overwork, sometimes by some intercurrent disorder. They consist of attacks of depression and lassitude, headache, smarting pains on micturition, and sometimes hæmaturia, neuralgic pains in the back, chiefly referred to the kidney. The patient often becomes hypochondriacal. This oxaluria is the index of a very low state of health (Gee). As an example, I may quote the following case:

A nervous, delicate, hard-working youth suffered from paroxysms of pain in the left side. Physical examination and a skiagram revealed nothing. The urine contained abundant crystals of calcium oxalate, but no albumen. The paroxysms generally came on if he overworked or took much muscular exertion; they left him fatigued and much depressed. Subsequently

he had two attacks of hæmaturia, the second rather severe, and accompanied by much pain. A stone was suspected, and his kidney was explored, but nothing was found to account for the symptoms. He had no more hæmaturia, but some occasional attacks of pain.

Treatment of Oxaluria.—The recognized treatment is abstention from oxalate-containing foods and administration of magnesia, since the oxalates are more soluble in the presence of magnesia. Peas should be taken when in season, as they are poor in oxalates and rich in magnesia. For Klemperer and Tritschler showed that when the amounts of CaO and MgO in the urine were about equal, as long as the urine contained 0·02 per cent. of magnesia, the calcium oxalate remained in solution, probably owing to the formation of a soluble double salt. And although the amount of oxalate deposited is no guide to the total oxalate excreted, it is only the deposit which causes the urinary symptoms.

Potassium citrate is of service in two ways—

1. As a diuretic it dilutes the urine.

2. By combining with the calcium it prevents the formation of calcium oxalate crystals. Martin showed that citrate threw calcium out of action by forming a non-ionizable soluble double salt. It is well known that citrate prevents the curdling of milk and the clotting of blood for this reason, and it has therefore been extensively used in the treatment of gastro-intestinal conditions and phlebitis.

I have employed them in oxaluria with success. Some observers prefer to employ lemon-juice to sodium or potassium citrate, and claim that in phlebitis, at any rate, it is much more effective. Now, if we can tell our patients that they need not give up strawberries altogether if they will also drink lemon squash, I believe we shall effect the desired object while avoiding irksome restrictions. A caution against much sugar while on this treatment should also be given.

An increase in urinary acidity will assist the solution of oxalate calculi, just as increased gastric acidity will assist the absorption of oxalates. Maguire has found the administration of acid sodium phosphate, in doses of up to an ounce a day dissolved in 100 ounces of distilled water, effective in diminishing the size of oxalate calculi. It is obviously important that there should be no ingestion of oxalates during this treatment, as the acid salt would facilitate their absorption.

In the nervous cases we must treat the digestive disturbance also, and direct attention to preventing fermentation of the sugar. A holiday and change of air is generally required.

Phosphaturia.

Normally phosphates are present in the urine as—

(*a*) Acid phosphates of sodium and potassium.

(*b*) Earthy phosphates of calcium and magnesium.

It is only the earthy phosphates that can form a deposit. This may occur—

1. In the bladder, so that the last portion of the urine is milky. This is often mistaken for spermatorrhœa; the patient becomes needlessly depressed, and falls an easy prey to quacks.

2. As an iridescent pellicle on the surface of the urine when it has been passed.

3. Only on boiling the urine, when acidification is necessary to prevent confusing it with albumen.

Calcium phosphate forms a deposit of stellar crystals, magnesium phosphate appears as rectangular plates with bevelled edges, while ammonio-magnesium phosphate (' triple phosphate ') forms ' knife-rest ' or ' coffin-lid ' crystals.

The term ' phosphaturia ' is somewhat loosely applied to any condition in which these various deposits occur. But it is clear that such deposit does not imply any increase in the total output of phosphates, since in no circumstances will the sodium and potassium phosphates be precipitated, while the earthy phosphates will be deposited on adding any alkali to any urine. Quantitative estimation would be necessary to prove an increase.

Usually phosphaturia is merely a sign of diminished acidity of the urine.

Now, if there be excessive secretion of hydrochloric acid in the gastric juice, the withdrawal of acid ions from the blood leaves less acid at the disposal of the urine during digestion. Phosphaturia is therefore common in hyperchlorhydria, even though a corresponding over-secretion of alkaline pancreatic

juice might have been expected to check its occurrence.

Many organic salts, such as citrates and tartrates, become bicarbonates in the blood, and thus reduce the acidity of the urine. Phosphaturia may therefore follow a diet rich in fruit and vegetables.

Again, if there be cystitis, ammoniacal decomposition will lead to a deposit of phosphates which will take the form of crystals of 'triple phosphates.' The occurrence of 'knife-rest' crystals at once suggests cystitis. In one case I saw, the passage of these crystals had occurred with hæmaturia at intervals for over a year. Between the attacks the urine was quite normal; but a stone was ultimately found. I have seen particularly copious deposits of triple phosphates in staphylococcal infections of the bladder.

There is, however, a residue of cases where the output is increased from the normal $2\frac{1}{2}$ grammes of phosphoric acid to perhaps 7 or 9 grammes. Here the earthy phosphates will probably be in excess. The ratio of earthy to alkaline phosphates, which is normally 1 to 2, may rise to 5 to 2. It was formerly thought that this was due to excessive breaking-down of the phosphates of the brain, as it is common in neurasthenia, but there is no proof of this.

Wasting causes an increased excretion of phosphates, because the disintegration of nucleo-proteins yields phosphates. Conversely, phosphates are diminished in the urine in pregnancy and in convalescence after fevers, because they are required for building up.

Phosphaturia may, therefore, be merely a symptom of wasting. Sometimes no definite cause for the wasting can be found. Thus the editor of a 'hustling' journal, aged thirty-eight, consulted me for loss of weight (28 pounds in two months). He was suffering from depression and 'brain-fag,' but there was nothing objective except phosphaturia. Tonics and alteration in his mode of life led to great improvement. Again, a man, aged fifty-two, was sent to me to find a cause of his loss of flesh. He had formerly been in a business which had declined so much that he had recently taken up a new occupation which entailed much walking. Some swelling of the legs came on, and he became very thin. Except some old adhesions round his shoulder-joint, which explained the pain and limitation of movement he experienced there, I could find nothing beyond phosphaturia. As he gradually became accustomed to his new occupation, he put on flesh again under ordinary tonic treatment.

I have met with marked phosphaturia in cases of multiple myeloid tumours leading to albumosuria. No doubt this was in consequence of the earthy salts being set free by the destruction of the bones.

Phosphaturia may also occur in cases of marked depression without wasting. It was the only objective sign I could find in a young man who had recently gone into business on his own account, and who consulted me for paroxysms of fear of failure. It was present also in the case of a young man of the anxious, nervous type, who was on the Stock Exchange, and

consulted me for headache, insomnia, and impairment of memory.

Probably the phosphaturia in these cases is symptomatic of a diminished formation of acid due to a general depression of metabolism.

In Ralfe's opinion cases of phosphaturia with wasting are apt to go on to serious organic diseases if they do not rapidly yield to treatment, but I have only observed such a sequence once. A man, aged fifty years, had much anxiety on account of the prolonged and ultimately fatal illness of his wife. He was much frightened because his urine had an iridescent scum on it. I found it was composed of phosphates, the urine being scarcely acid. Two or three years later he developed chronic interstitial nephritis, and had an attack of cerebral hæmorrhage which left him aphasic. I do not think, however, that there was any connection between the phosphaturia and this event. More probably the prolonged anxiety caused both depressed metabolism and high tension.

Treatment.—We must remember that phosphaturia is a symptom and not a disease.

1. If triple phosphates be present, seek a cause for cystitis and treat that.

2. If phosphaturia depends on hyperchlorhydria, the digestive condition requires treatment.

3. If it be associated with wasting, the cause of the wasting calls for attention.

4. If it be a symptom of depressed metabolism, the patient is usually much benefited by giving him the

acid he cannot make, preferably combined with tonics.

Now, phosphoric acid usually suits these patients well. If their symptoms were really due to phosphatic loss, this would hardly be the case, because there would already be excess of circulating phosphate, and the tissues could not discriminate between this and the administered phosphate. Moreover, on a fish diet, rich in phosphates but not acid, the phosphaturia will probably be aggravated. Therefore it is simply because it is acid that phosphoric acid does good, and in my experience it does not matter whether you give phosphoric or nitro-hydrochloric acid. But an inorganic acid should be given, and with it tincture of nux vomica.

If the deposit of phosphates makes the patient anxious, as it is apt to do, Soetbeer's method of diminishing the calcium intake may be used. Milk, eggs, fish, and fruit, which contain a good deal of lime, are not allowed, while food poor in lime, such as meat, potatoes, and cereals, is given. The phosphates are then excreted in more soluble forms.

It is an interesting point of contrast that neurasthenics tend to oxaluria with very acid urine, but to phosphaturia if the urine is not very acid.

Cystinuria.

Cystin is only an occasional constituent of urinary calculus. Its presence in more than minute traces

appears to be due to an inborn error of metabolism (Garrod). It is an amino acid containing sulphur and is contained in many proteins, being especially abundant in hair. The tendency to deposit hexagonal crystals in the urine is lifelong in some persons, and runs in families, more commonly in the males. Exceptionally the deposit of crystals has occurred in the tissues, imitating gouty tophi. Cystinuria is little influenced by diet, and indeed the patient can usually deal with large quantities of cystin given by the mouth. It is the endogenous metabolism which is at fault, the sulphur containing fractions of the tissue proteins being excreted as cystin instead of being further decomposed. The excretion of cystin is often accompanied by a variable amount of diamines, such as putrescin and cadaverin, which are not normally present in the urine and probably originate in the same way from incomplete breakdown of the tissue proteins. A cystin calculus is yellow, turning green on prolonged exposure to light, somewhat translucent, with a crystalline surface, rather soft and friable in structure.

Cystinuria may continue for years without producing calculi, and indeed an additional factor appears to be required before this occurs. The additional factor is an infection of the pelvis of the kidney, very generally due to *B. coli;* then the inflammatory colloids are provided, which glue the crystals together into a calculus. To render the urine aseptic is therefore the first indication in the treatment of cystin calculi, in order to prevent increase in size. The only

other suggestion as to treatment is based on the hypothesis that endogenous cystin should normally become the taurin of the bile salts, and that its excretion as cystin is due to lack of cholalic acid with which it can conjugate. Cholalic acid may therefore be given in cystinuria as the prophylactic against calculus formation. On the other hand, alkalies help to dissolve cystin when formed, but cannot check the formation of fresh crystals.

The factors in the deposit of uric acid, the other important ingredient of a calculus, have been considered in the preceding chapter.

CHAPTER VII

ALBUMINURIA AND THE TREATMENT OF NEPHRITIS

The causes of true or renal albuminuria may be classified thus (Tirard):

1. Without definite structural change of renal tissue—
   (*a*) Mechanical—*e.g.*, from failing heart.
   (*b*) Hæmatogenous—*e.g.*, in the anæmias and in fevers.
   (*c*) 'Functional.'
2. With definite structural change of renal tissue.

'Functional' Albuminuria.

This has also been called alimentary, postural, cyclic, adolescent, to mention only a few of the names. Alimentary albuminuria is extremely difficult to produce. Certain experiments by D'Arcy Power upon himself are usually quoted as evidence of its existence. It is true that albumen appeared in his urine on the first day of the experiment, after twelve eggs had been eaten, but it disappeared in the evening, and did not reappear till the afternoon of the third day, after the

consumption of forty-eight eggs. It was found again during the evening of this day, after which it disappeared again, and had not reappeared at the end of the experiment, by which time sixty-five eggs had been taken. Only once was the albumen present in sufficient amount to enable its coagulation-point to be determined, so that there was very little connection between the number of eggs consumed and the amount of albumen. A very significant point, which seems to have escaped notice, is that at this time D'Arcy Power was aged twenty-two, and that the occurrence of the albuminuria was always observed after a considerable amount of exercise had been taken. Now, transient albuminuria after severe exercise is common in young men, as we shall see, without excess of albuminous diet.

'Functional' albuminuria is not an uncommon condition in males between puberty and marriage. Dukes found it in 16 per cent. of all the boys entering Rugby School at the ages of thirteen or fourteen. The strain of examinations seems to be a factor. A young man I knew who was working for an examination in physiology happened to test his urine. To his alarm, it was loaded with albumen. He took a holiday, and the urine soon became free from albumen. Some years later the albumen returned during an intercurrent illness, again disappearing when he recovered from it. He is now a healthy man in busy practice.

The subjects of this condition are usually anæmic, weedy youths with a dull, heavy aspect, and a tendency to fainting. Dukes says that boys who faint in chapel

are almost certain to be albuminurics. Their hearts are often excitable, and the condition vaguely diagnosed in them as ' weak heart ' is frequently due to this.

Dukes divides them into three classes:

1. By far the largest class exhibit an increased arterial tension in consequence of irritability of the vasomotor nerves. The tension is, however, so unstable that it varies from hour to hour and day to day. This he regards as pathognomonic of the disease.

2. The next most extensive class comprises those who have cold, clammy, congested extremities, accompanied by a large, feeble, compressible pulse arising from deficient vasomotor control.

3. The remainder are the spare, highly-strung, oversensitive neurotics.

But albuminuria may occur after violent exercise in almost any young adult. Collier found albumen present in the urine of every one of the Oxford crew of 1906 after rowing a course. In the case of half of them the amount of albumen was quite large, and in men who went in for running races the albuminuria was even more pronounced. In all these cases he found the urine passed in the early morning to be free from albumen.

Cold bathing is another factor in inducing transient albuminuria, presumably by driving of blood from the periphery into the splanchnic area. The protein present is chiefly the serum albumen, to which the kidney is more permeable.

In the cases where albumen readily occurs without some special strain hyaline casts may be seen, and often calcium oxalate crystals. Posture has an important influence. Albumen is absent from the urine passed first thing on rising, because this was secreted while recumbent; but it appears in urine secreted while in the upright position. With the fainting and the variable tension this strongly suggests a vasomotor element. A lax condition of the vasomotor system failing to compensate for the effect of gravity would allow both cerebral anæmia and back pressure on the kidney to occur.

Observations of the blood-pressure confirm this; whereas change of posture has an insignificant effect on the blood-pressure of a normal person, there may be a difference of 40 millimetres between the pressure in the upright and recumbent position in these patients. I have seen a case in a girl where there was a variation of 35 millimetres.

Edel, in eight cases of this condition, found a fall of pressure under conditions which ordinarily cause a rise in the healthy man. Coincidently with this fall, albumen appeared in the urine. Facts such as these place vasomotor insufficiency in an indisputable position as the principal factor in this form of albuminuria, to which the name ' orthostatic ' may therefore fairly be applied.

Sir A. E. Wright believes that the coagulability of the blood is diminished in this condition, which would decrease its viscidity. Calcium salts increase both

coagulability and viscidity. He claims that calcium salts control 'functional' albuminuria, whereas organic albuminuria is not diminished, and may be increased. The subjects of 'functional' albuminuria have often been growing rapidly, so that there is an extra demand for calcium on the part of the tissues. He therefore considered the condition 'hæmatogenous' in origin, and allied to a 'serous exudate,' such as occurs in urticaria.

Whether we accept this view of the pathology of the condition or not, it provides us with a convenient clinical test for 'functional' albuminuria.

Fifteen grains of calcium lactate three times a day in water should control it. A possible fallacy is that the albumen often disappears spontaneously or is only present at certain times in the day. More systematic observations are required.

In six cases which I believed to be of this character the calcium lactate readily controlled the albumen, whereas in organic albuminuria I found it to have no effect as determined by Esbach's albuminometer.

Hingston Fox employed it in seven cases he thought were functional, and in all the albuminuria ceased, whereas in nine cases, apparently organic, albuminuria persisted.

While admitting this hæmatogenous element, we must not overlook the vasomotor element, which I believe to be of even greater importance.

Prognosis.—Dukes, who has probably had a unique experience of this condition, has entirely abandoned

his former opinion that it tended to organic kidney disease, for he has found that his patients even thirty years later were robust men. In fact, he has only found albumen subsequently in one of these cases, and that was in a boy who had only recently left school.

The question is one of great importance in connection with life insurance. At present the attitude of the offices towards albuminuria is one of total rejection or of heavy loading. Is this fair? I believe it is justified by some on the ground that the expectation of life is so much lower in albuminurics. Of course it is, if post-scarlatinal nephritis and other organic cases are included. They would naturally bring down the average. But has any attempt been made in such tables to exclude obviously organic cases? I believe not. Now that we have in calcium lactate a simply and readily applied test by which the functional can be discriminated from the organic, it seems to me that the rules of insurance companies and public services should be relaxed. It is not the duty of the medical man who examines for the companies or services to apply the test. Indeed, he has no business to treat as patients persons coming before him for examination. But the general practitioner can fortify his patient against the ordeal of examination by administering calcium lactate, and I can see no objection to his doing so; for he will not be able to secure the acceptance of sufferers from organic nephritis, but only of those who will almost certainly be free from albuminuria when adolescence is past.

Treatment.—Having assured ourselves by controlling the albuminuria by calcium lactate, by excluding the presence of casts other than hyaline, and by noting the effect of posture on the blood-pressure, that the case is one of orthostatic albuminuria, the first step in treatment is to reassure the patient. He usually comes before us, after the shock of rejection or postponement of his proposal for life insurance, believing himself to be the subject of an incurable disease, and is naturally apt to become hypochondriacal. Next a tonic line of treatment and a holiday are indicated, and usually that is all that is needed. I have used digitalis as well, and so far as I can judge the effect has been good, the general condition (such as the tendency to fainting) improving as well as the albuminuria ceasing.

Organic Albuminuria.

A defective kidney not only lets things pass out which it should retain, it also retains things which it should excrete.

Many of the symptoms are due to the latter factor. Thus, to take a simple example, the failure of the kidney to excrete water and salt is responsible for the œdema. In Bright's disease we have probably tended to lay too much stress on the albuminuria. In the chronic parenchymatous form no doubt the drain on the albuminous constituents may become serious, and a secondary anæmia results. But such high degrees of albuminuria are uncommon, and I think we are

beginning to realize that this one symptom has unduly dominated our conception of the disease. Von Noorden thinks that any wasting is just as much explained by the monotonous diet as by the loss of albumen.

It would be generally agreed that the orthodox, conventional treatment of chronic nephritis includes the following principles:

1. Severe restriction of protein intake with exclusion of food rich in albumen, such as eggs. In severe cases absolute restriction to simple milk diet.

2. The estimation of the amount of urea in the urine is to be taken as a guide to the capacity of the kidney.

3. The kidney is stimulated to increased excretion by the use of diuretics.

4. Elimination by the skin is promoted by various diaphoretic measures.

I venture to assert that each of these principles contains, and, indeed, is based upon, a fundamental fallacy.

I. Severe Restriction of Protein Intake. — When we proceed to limit the protein diet rigidly in Bright's disease, are we not led away by false analogies with glycosuria? Whereas there are the following essential differences:

(1) The sugar can be replaced by other things in a diet, while the protein cannot.

(2) The sugar excretion is preceded by an excess of sugar in the blood; albuminuria is not preceded by excess of albumen in the blood. The latter is due to a kidney lesion, the former is not.

(3) Recent work shows that there is a great breaking-down of the protein molecule into its constituent groups before it is absorbed into the body. The simple conception of Liebig, according to which the protein food is simply hydrolyzed into peptone, and then assimilated into the tissues with no further change than dehydration, is no longer held.

It has been well said that, just as a Gothic cathedral could not be built out of a classical temple without reducing it to its constituent stones, so the protein of the tissues cannot be built out of the protein of the food without splitting it up into its simple constituent groups.

There is, therefore, no satisfactory proof that albumen is absorbed as such, and is able to run through the body; consequently, it is difficult to believe that the protein of the diet can directly influence the degree of albuminuria.

I have tested this point several times by estimating the albuminuria on varying diets and comparing it with the urea and total nitrogen excreted.

As an example the following case of parenchymatous nephritis may be taken:

Diet.	Albumen Nitrogen.	Total Nitrogen, less Albumen Nitrogen.
	Gramme.	Grammes.
Milk diet, and one pint beef-tea	0·562	6·17
,, ,, only	0·6	7·46
,, ,, and one egg.. ..	0·69	9·77
,, ,, and two eggs ..	0·7	7·91
,, ,, and three eggs ..	0·649	7·6

These figures represent the average of several days on the same diet, so as to avoid disturbances due to the diet of one day not being eliminated till the next. From them it can be seen that the addition of three eggs to the diet did not really affect the albuminuria.

We know now the physiological minimum of protein is much less than the 100 to 125 grammes formerly ordained. Chittenden's experiments on the effect of a reduced protein diet are by now familiar to all. From observations on himself, his assistants, students, and a squad of soldiers, he concluded that weight and nitrogenous equilibrium could be kept up on 50 to 60 grammes protein a day or even less, with no diminution, but rather an increase, of physical or mental fitness.

In the following typical diet given by Chittenden the total protein amounted to 41 grammes. *Breakfast :* Coffee, cream, milk, sugar. *Lunch :* Omelette, bacon (10 grammes), potatoes, butter, bread or biscuit, fruit and sugar. *Dinner :* Beefsteak (34 grammes) or lamb chop (32 grammes), peas, mashed potato, bread-and-butter, salad, biscuits, cream cheese, coffee and sugar.

A number of workers in one of the London physiological laboratories recently tested what amount of protein each was taking in the day; no alteration was made in their ordinary meals. With one exception, they were all taking less than the Voit standard, and one was taking only about 60 grammes. Thus a representative group of brain workers in this country tends to eat a very moderate amount of nitrogenous food,

which may be taken to confirm Chittenden. He has certainly proved a point of great interest and importance—that the minimum protein requirements of the body are much less than was supposed. But he goes much further, and maintains that the minimum is also the optimum. To consume protein in excess of that required for the repair of the tissues he regards as a physiological sin, the wages of which is migraine in earlier and cardio-vascular degeneration in later life. He gives no evidence of this, but assumes that the nitrogenous excess overtaxes the kidneys by which it has to be excreted. Why he assumes that the kidneys are unable to do more than the minimum necessary without damage to themselves is hard to see. He might as well assert that the deeper breathing necessitated by reasonable exercise dangerously overtaxes the capacity of the lung to excrete CO_2, and tends to asphyxia. He is, in fact, obsessed with the old idea that the body is unable to make any other use of protein food than to repair tissue waste—an idea which other lines of work have rendered improbable. The physiological minimum is not necessarily the physiological optimum. Experience goes to show that there live, side by side, a race living on a protein-rich diet and one on a protein-poor diet, such as Europeans and natives in India, the morbidity and mortality of an epidemic are much higher in the latter. The rapid rise of Japan corresponds to the adoption of a more liberal nitrogenous diet. To this Chittenden answers that prosperity causes an individual or a race to elabo-

rate the menu, that the increased food is not the cause of the improvement.

Of our protein diet very little is used for direct repair of tissue waste, but doubtless much of the rest is used as a source of energy, and it is at least probable that the ammonia groups set free from this protein excess are useful in neutralizing acids which might otherwise lead to acid intoxication; moreover, protein in moderate excess of minimum requirements gives the tissues a wider choice of building material from which to select. In Hutchison's phrase, protein is one of those things of which it is necessary to have too much in order to have enough.

II. Urea Estimations as a Guide to the Renal Capacity.—Formerly I used to estimate the ratio $\frac{\text{Urea N}}{\text{Albumen N}}$ on different diets, and if it increased when the protein of the diet was increased, I concluded the increased diet was beneficial, as the patient was metabolizing it. But I have abandoned this view. For consider what happens when we give a normal individual an excess of protein food: he turns it into urea, and excretes it as quickly as possible. The mere fact that the nephritic can turn his protein into urea does not prove he has done any good with that protein. Indeed, evidence is accumulating that such protein excess never gets built up into protoplasm at all.

For this reason it seems to me that the amount of urea secreted in the day gives very little information

as to the severity of a case of Bright's disease unless the diet is carefully taken into consideration.

The procedure often adopted is irrational. A man with chronic nephritis on a restricted diet has his urea estimated. Instead of the normal 30 grammes, he is found to be passing, say, only 16. The physician concludes that the capacity for urea excretion must be seriously decreased; the patient must take less nitrogenous food. This is done, and the next analysis shows an even lower urea excretion. 'Worse and worse,' thinks the physician; 'this man is only fit for a milk diet.' Accordingly he is given three pints of milk a day and nothing else. He now bids fair to fulfil the gloomy prognosis formed, unless he fortunately rebels against this pitiful fare, and takes the law into his own hands. For, as the greater part of the urea comes direct from the food, the more the nitrogenous food is restricted the less urea will be excreted.

Of course, a patient on the diet ordinarily given in nephritis passes less urea than normal, because he is given a diet poor in protein. But the output probably will not be so little as that of a healthy fasting man, while it will certainly be more than that of a man on Folin's diet of starch and cream, in which the nitrogenous excretion is reduced to a minimum, because so much of the energy is derived from sources other than protein.

What the physician expects to learn from the urea estimation without reference to the amount of nitrogen

in the food is hard to say. If he knew the total nitrogen excreted, as estimated by Kjeldahl's method, he could see whether the body was converting a due proportion of the nitrogen into urea; this would give him some information as to the capacity of the individual, but urea estimations by themselves tell him practically nothing. This fallacy vitiates many of the conclusions arrived at by so careful an observer as the late Professor Foxwell (*Lancet*, 1908, vol. ii., p. 1425). He hardly mentions the diet factor at all. In one case he certainly says that he found a patient with chronic nephritis passing as much as 585 grains (39 grammes) of urea a day. On inquiry, he learned that the patient, feeling run down, was taking six meals a day, three of them being good meat meals. This shows that a chronic nephritic can excrete even more than a healthy man does on his ordinary diet, though it presumably taxes his kidneys more. We can agree with Professor Foxwell that a daily output of 250 grains of urea is the lowest on which a man can permanently exist without losing ground; for this would represent a daily intake of about 50 grammes of protein, which is little enough to satisfy even the most extreme 'nitrogen economist.' In short, the amount of urea excreted by the kidney depends on the amount of protein eaten, and, within wide limits, on little else.

What is the bearing of all this on the dietetic treatment of chronic nephritis?

Too rigid a limitation of the protein diet with the idea of diminishing the albuminuria is bad, because

it cannot effect the desired object, and deprives the patient of an essential form of nourishment. On the other hand, an excessive protein diet is inadvisable, even if the patient can metabolize it, because he is getting the energy in a form that throws work on to the damaged excretory organs. What is the happy mean ? I would suggest that we can arrive at it thus:

Chittenden's diet gives us the physiological minimum of protein. As the amount of protein in the diet has no appreciable effect on the amount of albumen in the urine, a patient with nephritis would not be able to maintain his nitrogenous equilibrium on Chittenden's diet. We must add an amount of protein equal to the albumen lost in the urine,* when we shall be giving just enough to maintain equilibrium and yet not be taxing the kidney by calling upon it for any unnecessary work.

Von Noorden finds, clinically, that the chronic nephritic can easily excrete up to 15 grammes of nitrogen in the day, but above this elimination becomes irregular and uncertain. Fifteen grammes of nitrogen corresponds to 94 grammes of protein, and this is the maximum that should be allowed, while the minimum

* A convenient rule is this: When the reading of the albuminometer is 5 and the amount of urine is 2 pints, the patient is excreting as much protein as is contained in one egg. I take these figures because they admit of simple proportional calculation, and also because they represent the amount of albumen excreted in a case of chronic parenchymatous nephritis of average severity—*i.e.*, 6 grammes, which is the amount of protein in one egg.

is about 60 plus the amount of albumen in the urine. Thus the theoretical and practical results agree fairly closely.

We should naturally avoid meat-extracts and cellular organs, such as sweetbread, because they contain a large proportion of purins which, though useless for nutrition, have to be excreted by the kidney, and according to von Noorden the damaged kidney excretes uric acid with difficulty. This is contrary to the principle of physiological rest. But we must equally avoid the monotony of diet which leads to failure of appetite and consequent wasting, while it is incapable of affecting the albuminuria. We can safely permit a much greater variety of diet than is allowed on the orthodox lines. For instance, I believe from my analyses that eggs and things made with eggs certainly may be allowed. Raw eggs are probably unsuitable, as they may contain substances irritative to the kidney.

It is undesirable to restrict such patients to milk, which is too dilute a form of food for them, and may increase the œdema. Salt should not be allowed, since it is badly eliminated in many cases of nephritis, and, accumulating in the tissues, increases the œdema by raising the osmotic pressure. Indeed, as Bryant found, even a man with healthy heart and kidneys may develop œdema as the result of taking excess of salt. The substitution of butter and lemon-juice will usually satisfy the patient.

In following this plan we shall avoid adding to the

miseries of sufferers from an incurable disease by enforcing unnecessary restrictions. If it be desired to guard against the dangers of possible nitrogen retention, Ernberg's plan may be followed of interposing periods of a week or a fortnight during which a diet poor in protein is taken. But prolonged nitrogen starvation is as bad for a nephritic as for anyone else.

The rules which guide us in acute nephritis or in exacerbations of chronic nephritis are somewhat different, however. ' In acute affections we concentrate our attention on the diseased organ, whilst in chronic cases we keep the general condition of the patient more in view ' (von Noorden). Nitrogen retention is a very prominent feature of acute nephritis, and a diet poor in nitrogen is strongly indicated. This period of retention is usually short; if it continues, it is very ominous. A few days' comparative nitrogen starvation will do no harm, and may avoid grave danger.

Von Noorden is of opinion that in acute and dangerous cases this is very necessary, and gives nothing but sugar, water, and fruit-juice for from three to eight days. I also allow toffee if desired, for it is merely composed of butter and sugar and allays hunger.

The degree of albuminuria gives no real clue as to the gravity of acute nephritis. At my suggestion, Dr. F. W. W. Griffin examined the nitrogenous excretion in a series of cases of scarlatinal nephritis from the beginning. He found that, whereas there was a general relation between the amounts of water, urea, and total nitrogen excreted, there was none between these and

the amount of albumen excreted. He concluded that the albumen afforded no more than a danger-signal at the beginning, and could not be accepted as a trustworthy indicator of the excretory capacity of the kidney.

III. The Use of Diuretics in Bright's Disease.—There has always been a tendency to regard 'flushing out' the kidney as a good line of treatment in Bright's disease; but before employing it we should consider what method of diuresis we mean to employ, how far such methods are desirable in the case before us, and how far they will achieve the end desired. Routine and indiscriminate 'flushing out' is to be deprecated.

Methods of producing Diuresis.—The following are possible:

1. *By vaso-dilatation in the kidney*, as by the caffeine group of drugs. These probably act as direct stimulants to the renal epithelium, the vascular change being secondary.

2. *By vaso-constriction elsewhere*, in consequence of which the blood-pressure is raised and more blood is forced through the kidneys; digitalis has generally been held to act in this way.

3. *Increase in quantity of circulating fluid*—(*a*) by absorption of water from the intestine, as by giving the patient large quantities of fluid to drink; (*b*) by increasing the osmotic pressure of the blood. The saline diuretics, citrates, acetates, etc., act in this way, attracting water from the tissues into the blood-stream.

How far are these methods desirable in nephritis?

1. Why stimulate a damaged structure? I believe I have seen caffeine, theobromine, and diuretin all produce bad effects. It is chiefly in chronic parenchymatous nephritis that one sees them employed, and there is a danger that they will cause a return of acute symptoms; hæmaturia not infrequently follows.

I have gradually come to the conclusion that this group of drugs is unsuitable for nephritis, and should be restricted to cases where diuresis is required and the kidneys are not organically diseased.

2. Digitalis: If the blood-pressure is already raised, why raise it any further? I saw a case of chronic interstitial nephritis with dilating heart, which was causing a diminished urinary secretion. Digitalin injections were being given. The blood-pressure was 200 millimetres. I argued that the main difficulty was that the heart could no longer work against such high blood-pressure, and suggested nitro-glycerine and strophanthus instead; the pressure fell, and the patient was relieved for the time. I believe the unsatisfactory results, which digitalis sometimes gives, are due to its being employed in unsuitable cases such as this. It is, indeed, difficult to see how digitalis could be a satisfactory diuretic in cases of nephritis, even accepting the modern view that it is not a vaso-constrictor in man.

3. In acute nephritis it is really no good to give large quantities of water with the idea of flushing the kidney, for the kidney cannot excrete it, so that it accumulates in the tissues, increasing the œdema.

The importance of this defective adjustment of the kidneys to varying water-supply is shown by the following observation of von Noorden's: A normal individual, with an average hourly diuresis of 52 c.c., excreted an average of 723 c.c. for three hours after drinking 1,800 c.c. of Salvator water; under the same conditions a patient with acute nephritis, excreting 91 c.c. hourly before, only passed 103 c.c. after. Spontaneous diuresis is the first and surest sign of convalescence.

The attempt to increase the urinary flow by increasing the osmosis into the blood is less open to objection in acute nephritis. Citrate of potassium renders the urine less acid and, therefore, less irritating to the kidney. As the extra water is drawn from the tissues, it will tend to diminish, and cannot increase, the œdema.

I would put it in this way:

(*a*) *In acute nephritis* we cannot flush out the kidney, because the inflamed organ will not respond. I believe that potassium citrate is the best drug, because it does not irritate the kidney, and any diuretic effect it may have is at the expense of the œdema.

(*b*) *In chronic parenchymatous nephritis* the kidney is more responsive, but it is undesirable to increase its secretion, either by irritating it by caffeine and the like or by increasing the already raised pressure. I am inclined to make an exception in favour of theocin-sodium acetate in small doses, such as 2 grains twice a day. It appears to increase the permeability of the

kidney, and, although allied to caffeine, does not seem to irritate the kidney in these doses. The saline diuretics seem to be free from objection. In addition to potassium citrate I have given, with apparent benefit, the following mixture:

Liq. ferri acetat.	..	..	..	♏xv.
Liq. ammon. acetat.	..	..	..	ʒii.
Aq. camph.	..	..	..	ad ʒi.

(*c*) *In chronic interstitial nephritis* the kidney responds quickly to altered intake of water. But some years ago von Noorden claimed that, rather than trying to flush out the kidney, it was desirable to restrict the fluids to 1½ litres a day. He maintained that this did not diminish the urea excretion, while the work of the heart was spared. He considered that the polyuria was secondary to polydipsia. To a limited extent this is true, but the kidney has lost the power of excreting a concentrated urine, so the restriction must be carried out with caution.

IV. Elimination by the Skin.—This method of treatment is open to the following objections:

(*a*) Only 3 grammes of nitrogen can be got rid of through the skin in the day compared with 8 grammes that can be more easily eliminated by the bowel.

(*b*) Physiological rest for the kidney is not secured by giving it a highly concentrated urine to deal with, for defective adjustment of the kidney to varying concentration of the urine is a prominent feature of nephritis.

(*c*) Diaphoresis is an exhausting process and may depress the heart.

(*d*) The withdrawal of so much fluid without a corresponding removal of organic solids must increase the concentration of the toxins in the circulation. If, therefore, it is decided to employ diaphoretic measures, it should be after fully weighing these objections as applied to the particular case. It has been urged in support of this method of treatment that, after a hot-air bath, the patient may be actually covered over with small crystals. These crystals, however, in the main, do not consist of urea but of sodium chloride; and here we have the clue to the kind of case in which diaphoresis will be of service—namely, that in which there is a defect in the elimination of sodium chloride with consequent œdema, for the retained salt increases the osmotic pressure of the tissues, and this tends to increase œdema and to diminish excretion. The elimination of salt by the skin may therefore be of indirect service by breaking a vicious circle. In a case of this sort I have actually seen diaphoresis followed by diuresis, which can only be explained in this way.

It may fairly be objected that I have attempted to destroy the basis for treatment without being able to put anything in its place; to a certain extent, this is true. The kidney, once damaged by chronic nephritis, cannot recover, and the only thing which can be done is to attune the mode of life to a low key, subjecting the patient to as little strain as possible. He must be

warmly clad and the kidneys protected from fluctuations of temperature as far as possible. The bowels must be kept freely open, as the best alternative route for elimination of toxins. He may have a considerable variety of food provided that the intake of protein does not fall below 60 or rise above 90 grammes in the day, and provided that he takes very little purins and salt. In constructing the dietary it will be convenient to remember that a pint of milk, one egg, a $\frac{1}{4}$ pound of fish, and 2 ounces of meat contain altogether 72 grammes of protein. Allowing for the protein in bread and vegetables, it will be seen that the amount of nitrogen in this diet errs rather on the side of liberality. It will, however, serve as a rough guide. He can be helped by saline diuretics and unirritating preparations of iron. He will do all the better if his medical man realizes that many of the methods recommended in the treatment of this disease are impotent where not actually harmful.

CHAPTER VIII

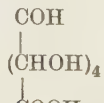
GLYCOSURIA AND DIABETES

A MEDICAL man is often faced with the problem of deciding whether a patient is suffering from diabetes when his urine reduces Fehling's solution.

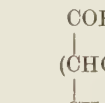
Certain substances other than sugar might be responsible for the reduction.

1. Uric acid and kreatinin may both cause reduction, and are normal constituents of urine. But they are never present in sufficient amounts to cause reduction, if we are careful to add only as much urine as we have taken of Fehling's solution.

2. Glycuronic acid is closely related chemically to dextrose, as is seen by comparing their formulæ:



Glycuronic acid.



Dextrose.

The reason for its appearance in the urine would appear to be that it has combined, like sulphuric acid, with putrefactive bodies or else with administered drugs, such as chloral, morphia, camphor, chloroform,

antipyrin, antifebrin, or pyramidon. Its function in this connection would appear to be antidotal, the conjugated acid being harmless. In this way protection against certain toxic substances is obtained.

Glycuronic acid may be present in fresh urine without causing any reduction, when, of course, confusion will not arise. Boiling for some time with 5 per cent. sulphuric acid will render it strongly reducing, however. Should a reduction be given with the untreated urine, glycuronic acid can be distinguished from dextrose by its failure to ferment. If it is found in the urine of a patient not known to be taking one of the drugs mentioned above, the test for indican (p. 262) should be tried, for it may simply be due to an unusual absorption of putrefactive bodies which are thus rendered inert. But if indican is not found, the suspicion of drug habits on the part of the patient may justifiably be entertained.

3. Alkaptonuria may be responsible. This ' is not the manifestation of a disease, but is rather of the nature of an alternative course of metabolism, harmless and usually congenital and lifelong ' (Garrod). The individual appears to be incapable of breaking down the tyrosin in the protein molecule completely, so that the intermediate product, homogentisic acid, appears in the urine. But the urine does not ferment, and it darkens on standing, or at once, on the addition of alkalis. It may stain the linen brown. When a dilute solution of ferric chloride is allowed to fall, drop by drop, into the urine, each drop produces a transi-

tory deep blue colour. Ochronosis—blackening of the cartilages and ligaments, and sometimes of the conjunctivæ—may occur. Usually there is a chronic arthritis also, which may lead to a curious 'goose gait.'

Other sugars than dextrose may be the cause of the reduction.

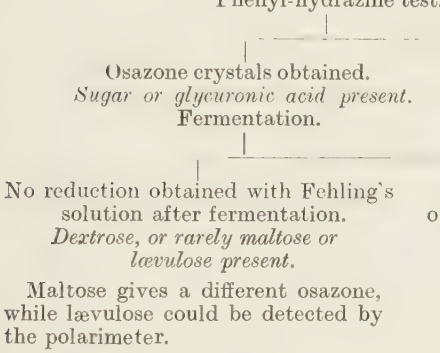
(*a*) Lactose is often present in the urine during and on the sudden cessation of lactation, and occasionally during pregnancy. Any lactose reabsorbed from the mammary gland cannot be utilized by the tissues because it is a disaccharide, and all carbohydrates must be broken up in the intestines into monosaccharides before they can be assimilated. But alimentary lactosuria is also very easily produced in women who are suckling, showing that their capacity for metabolizing lactose is physiologically depressed.

(*b*) Pentose exceptionally occurs in the urine. Its presence is due to a congenital incapacity to metabolize the pentose sugars set free in the breakdown of nucleo-protein. It may not reduce until the urine has been boiled for a few minutes, when the reduction takes place suddenly. It does not ferment, and may be further identified by the green colour it gives with orcin and hydrochloric acid. It is not a manifestation of disease.

(*c*) Lævulose may be present as well as dextrose in alimentary glycosuria. Alimentary lævulosuria can be easily excited in diseases of the liver, in which it has some diagnostic value.

When equal parts of hot urine and hot Fehling's

solution are mixed and yield an orange precipitate *without reboiling*, it is almost conclusive evidence of the presence of dextrose or lævulose (Garrod). If it be desired to prove beyond a doubt that the reduction is due to dextrose, the following scheme may be used:


Phenyl-hydrazine test.
Osazone crystals obtained.
Sugar or glycuronic acid present.
No osazone crystals.
Absence of dextrose.
Fermentation.
No reduction obtained with Fehling's solution after fermentation.
Dextrose, or rarely maltose or lævulose present.
Maltose gives a different osazone, while lævulose could be detected by the polarimeter.
Reduction still obtained after fermentation.
Not due to dextrose.

Before considering the significance of glycosuria, we must recall what a normal man can do with ingested sugar.

1. He can store it as glycogen.
2. He can store it as fat.
3. He can use it at once for muscular energy.
4. Any excess that cannot be dealt with in these ways will pass out into the urine. Anyone will have glycosuria after taking enough *sugar* at one time. The limit of this assimilation for the principal sugars is as follows:

Dextrose or cane-sugar ..	150—200 grammes.
Lævulose	150 grammes.
Lactose	120 „

This may be considered to be 'physiological glycosuria.' But glycosuria after any quantity of *starch* is not physiological. In Naunyn's phrase, a patient who passes sugar after the free ingestion of starch is virtually a diabetic.

Von Noorden believes that the obesity which often precedes the onset of glycosuria in middle life is due to a loss in the power of glycogen storage, while the power of conversion into fat is still retained. The body will not allow a valuable foodstuff to escape if it can be avoided; therefore a stage of rapidly increasing obesity is met with, which he terms 'latent glycosuria.' But this cannot be maintained indefinitely, and overflow of sugar into the urine will occur—consecutive glycosuria.

Even in patients who do not ordinarily pass sugar there may be a lowered tolerance for carbohydrates. This lowered tolerance may precede the glycosuria and outlast it. It indicates that the metabolic defect that caused the glycosuria is still present, and that the sugar may return on slight provocation. In all but one form of glycosuria there is excess of sugar in the blood—hyperglycæmia. This may also precede and outlast the glycosuria, and has a similar significance to lowered sugar tolerance. The estimation of sugar tolerance and the sugar content of the blood is a valuable guide in estimating the reality of an apparent recovery from glycosuria.

It will systematize our conceptions of diabetes to consider the ways in which glycosuria may be

experimentally produced, and then the clinical equivalent.

1. *Phloridzin Poisoning.*—Phloridzin produces glycosuria by its action on the kidney tubules, for if injected into one renal artery the glycosuria occurs sooner, and to a more marked degree, on that side; consequently, there is no excess of sugar in the blood, but rather a deficiency. For some time no clinical equivalent of this was recognized, but lately cases have been recorded without excess of sugar in the blood which were uninfluenced by diet. The prognosis appears to be more favourable than in ordinary glycosuria. The condition has been called ' renal glycosuria,' and it has been compared to that produced by phloridzin. A case recently described by Dr. Garrod warns us, however, against coming to this conclusion hastily. A boy was admitted with ' renal glycosuria,' but his elder sister was in hospital at the same time with typical diabetes. This hardly suggests that it is an entirely separate entity; but at any rate it is established that glycosuria can exist without hyperglycæmia, and I have a case at present under my care with definite hypoglycæmia.

2. *Excision of the Pancreas.*—Lancereaux was the first to maintain the association of pancreatic disease with diabetes. Intralobular fibrosis is the most common change to find in the pancreas in severe diabetes. The pancreas may be the site of malignant or cystic disease without diabetes. There must be a more extensive destruction of the secreting tissue than usually

occurs under such conditions. In many cases of typical diabetes there is no evidence of structural change in the pancreas.

Rose Bradford has recorded a case where a large pancreatic tumour was seen at an exploratory laparotomy; three years' later the patient was found to be suffering from severe diabetes, and the tumour could no longer be detected. Recently I had a case illustrating the converse condition. A woman who had been admitted for diabetes returned three years later with all the signs of obstruction of the common bile-duct and the pancreatic duct. As she was sixty years of age, I suspected new growth of the head of the pancreas, but under treatment the obstruction disappeared, though the glycosuria persisted. Such cases suggest that diabetes may have a pancreatic origin, even though there is no evidence of disease of the gland at the time the glycosuria is observed.

Systematic use of the tests for pancreatic insufficiency will in future enable more of such cases to be recognized (see also Chapter IV.).

3. *Adrenal Glycosuria.*—Injections of adrenalin are known to excite glycosuria, as when the drug is used for asthma. Von Noorden regards the chromaffin system, of which the adrenals are the most important part, as antagonistic to the pancreas in regard to sugar metabolism. Loewi's adrenalin eye-test for pancreatic disease, already described, is based on this antagonism, and may prove a help in determining whether a given case of diabetes is pancreatic in origin.

Organic disease of the adrenals does not cause glycosuria, because there is deficiency of the internal secretion; indeed, in Addison's disease, there is increased tolerance for sugar. But it has often occurred to me that chronic over-action of the adrenals may afford a possible explanation of the frequent association of glycosuria with high tension in men in later middle life; for both these can be produced by excess of adrenalin. The influence of the nervous system in inducing this will be referred to later.

4. *Thyroid Glycosuria.*—Thyroid extract can excite glycosuria. Myxœdema is associated with increased sugar tolerance, while in Graves' disease sugar tolerance is lowered, and there may be actual glycosuria. Hence the myxœdematous patient becomes stout, while the sufferer from exophthalmic goitre emaciates; but even in myxœdema the administration of thyroid extract may cause glycosuria. Garrod found it in four out of eleven cases. The proper dose of thyroid extract in myxœdema is one which does not lower sugar tolerance appreciably below the normal. The drug is not suitable for the treatment of obesity, as it may convert a latent into an active glycosuria, for many stout subjects are on the verge of glycosuria. According to von Noorden, the internal secretion of the pancreas is inhibited by the thyroid, hence the glycosuria which follows thyroid excess.

5. *Pituitary Glycosuria.*—We have already seen that the posterior lobe of the pituitary body is a potent factor in controlling carbohydrate metabolism. In

the active stage of acromegaly there is always lowered sugar tolerance and not infrequently glycosuria, due to excess of this secretion. As the disease progresses and the posterior lobe is destroyed, the sugar tolerance rises and may become very high, as it is in the cases of primary hypopituitarism, known as 'Frölich's syndrome.' The development of this exaggerated sugar tolerance may be delayed by compensatory enlargement of the thyroid. The secretion of the posterior lobe appears to excite glycosuria in exactly the same way as thyroid extract—namely, by inhibiting the internal secretion of the pancreas.

6. *Puncture Glycosuria.*—Recent observations have tended to alter considerably the significance attached to Claude Bernard's classical experiments. It was soon found that puncture of the fourth ventricle excited glycosuria by setting up some nervous irritation, which was believed to act directly on the liver. Then it was noted that previous section of the splanchnic nerve or painting nicotine on the ganglia concerned would prevent the puncture from producing its usual effect. And now it appears that the nervous impulses excited pass, not to the liver direct, but to the adrenals, causing them to throw more of their secretion into the circulation. In short, puncture glycosuria is adrenal glycosuria. The clinical equivalents of this process are seen in the glycosuria of concussion, cerebral tumours, cerebral hæmorrhage, pineal cysts, and the like. But we must remember now that there may be another way in which these conditions may excite a

temporary glycosuria, and that is, by pressing on the posterior lobe of the pituitary body, and squeezing an excess of its secretion into the cerebro-spinal fluid.

I have come across several instances of cerebellar hæmorrhage, which, on account of glycosuria, have been mistaken for diabetic coma. A man walking along the street suddenly felt so faint and giddy that he had to cling to some railings. He was taken to a doctor, who gave him brandy and injected strychnine, whereupon he became unconscious. When he was brought to the hospital comatose, the house-physician passed a catheter and found sugar in the urine. He was treated for diabetic coma by bleeding and infusion of alkalies, but died in a few hours. At the post-mortem examination the urine in the bladder did not contain sugar, and a hæmorrhage was found in one lobe of the cerebellum, which had pressed on the fourth ventricle. I have seen the same thing in a lenticulo-striate hæmorrhage, where the blood had been effused into all the ventricles. In the case here related the sudden onset was unlike that of diabetic coma; but the mistake is very liable to occur in hospital practice when a patient is brought in already comatose, and no clinical history can be obtained. In such circumstances the test for diacetic acid with perchloride of iron becomes of paramount importance, for it will always be found positive in diabetic coma, while it is negative in this type of glycosuria.

7. *Asphyxial Glycosuria.*—In any asphyxial condition glycosuria may occur; this is probably the cause

of post-anæsthetic glycosuria, and of the glycosuria of tuberculous meningitis, to which Garrod and Frew have called attention. It appears when the respirations are shallow and grouped. The distribution of the meningitis does not support the idea that the glycosuria results from the pituitary body or the medulla being involved; it is not the deficiency of oxygen but the excess of CO_2 that is responsible. On passing a stream of carbon dioxide through, serum sugar is set free. Carbon dioxide can combine with proteins, especially globulins, and in doing so apparently turns sugar out. This supports Pavy's hypothesis that sugar is normally linked to proteins.

A number of drugs may excite a temporary glycosuria, but they do not throw any further light on its pathology. It is worth while, however, to call attention to the special influence of champagne in this respect, because nervous persons are apt to fortify themselves against the ordeal of life insurance examination by its aid, with results that are distinctly unpleasing.

It will be seen that the present conception of glycosuria is that it is usually due to a disturbance in the balance between the internal secretions. In a few cases the defect appears to be at the very door of entry of the sugar into the blood, the intestinal mucosa, but more usually it is further on. The stream of sugar entering the portal vein is carried to the liver, but on the way it encounters the internal secretion of the pancreas, which enables the sugar which is not stored directly as glycogen to be utilized by the tissues. This

internal secretion is antagonized by those of the adrenals, thyroid and pituitary, though the first of these appears also to have a direct effect in emptying the glycogen reservoirs, so that the pancreatic defect may be absolute or merely relative, due to overaction of other glands. This explains the frequent failure to find a pancreatic lesion in fatal diabetes. The glycosuria of pregnancy is also probably due to disturbance of this balance, for enlargement of the thyroid is well known to occur in pregnancy, and more recently enlargement of the pituitary has also been demonstrated. It is noteworthy that the one organ which is most obviously connected with carbohydrate metabolism, the liver, seems to play little part in the pathology of diabetes. As von Noorden says, there are no grounds for assuming that its chemical processes are qualitatively other than normal.

Pavy urged that a comparatively small crystalline molecule, like dextrose, would necessarily escape by the kidney unless it were linked on to a larger molecule, such as protein. The internal secretion of the pancreas might provide links or amboceptors for this purpose.

Even in a healthy person, a sudden rush of ingested sugar may overtax the supply of amboceptors, and unattached sugar molecules overflow into the urine. If the amboceptors are deficient, there will be this overflow after the ingestion of an ordinary carbohydrate meal—alimentary glycosuria. If the amboceptors are very gravely deficient, not only will the sugar from the food appear in the urine, but the sugar from

the tissues will also pass into the urine. The tissues are now in a condition of sugar starvation, and in starvation the autolytic enzymes come into play. By the break-down of the cells fresh sugar molecules are set free, not merely from glyco-proteins, but from amine groups like alanin in the true protein molecule. These are equally unable to be used by the tissues which need them, because the combining link is missing.

Mild cases may become grave if deluged with carbohydrate, while severer cases may acquire a limited tolerance for carbohydrate if properly regulated—that is to say, the types shade off into one another. This suggests some cause which is capable of quantitative alterations, such as a varying number of amboceptors.

That there is a mild stage without symptoms is proved by the way in which examiners for life insurance find glycosuria in young proposers for policies. There seems a curious liability for a potential glycosuria to become actual under the stress of examination for life insurance, and I have seen several interesting examples of this. Sometimes there has been intermittent glycosuria, which later has become permanent. If it had not been for the insurance examination the glycosuria would remain unsuspected in such cases until the onset of some marked symptom. It points to the conclusion that patients usually suffer from glycosuria for some time before symptoms ensue.

If an examiner for life insurance finds acetone bodies present in the urine without sugar, he should at once

suspect that dieting has been practised with the view of enabling a glycosuric to pass muster. A test-meal of 3 ounces of sugar dissolved in water should be given, and the urine tested again an hour later. This is useful also in cases of suspected alimentary glycosuria without the question of attempted fraud.

There would be general agreement, I suppose, in designating the following as examples of mild and severe cases of glycosuria respectively. It would be a mild case if the patient were over forty and not wasting, his tongue not raw, though perhaps covered with a black 'hairy' fur. The urine would contain no acetone bodies. Restriction of the diet would cause sugar to disappear quickly; probably acetone bodies would make a brief and slight appearance now, but so they would in anyone on a suddenly restricted diet. Exercise would cause a diminution of the glycosuria, which shows that sugar could still be utilized by the tissues. A typically severe case would be one in a patient under thirty, who was wasting and had a raw 'beefy' tongue. The knee-jerks might be absent. Diacetic acid would be present in the urine, and sugar still present on a restricted diet. Acetone and diacetic acid would be markedly and persistently increased by a sudden restriction of the diet, and exercise would cause an increase in the glycosuria, indicating that the body was unable to utilize even the sugar set free from the breakdown of its own tissues.

If we had merely to deal with two such distinct classes as these, there would be little difficulty in dis-

tinguishing between so-called alimentary glycosuria and diabetes. But, unfortunately for the classifier, all shades of intermediate cases are met with.

Association of Albuminuria with Glycosuria.—There are two conditions in which we may meet with both albuminuria and glycosuria, and the relative importance of the abnormal constituents of the urine is quite different in each.

(*a*) A patient with granular kidney is very likely to be 'gouty,' and as such may have glycosuria, more usually of the amenable type. I have seen a striking example of the way in which the glycosuria may mask the more important symptoms of the nephritis. A man who had both albumen and sugar in his urine developed tingling, numbness, and some loss of power in the left side, and became drowsy. His doctor feared that diabetic coma was impending. When, however, I found that there was no diacetic acid in the urine, but that the volume of the urine was diminishing, that the blood-pressure was high, and the aortic second sound was greatly accentuated, I concluded that it was uræmia rather than diabetic coma that was to be feared. Vigorous treatment was directed towards lowering the vascular tension, and the glycosuria was ignored for the time being. Rapid improvement followed.

(*b*) Prolonged glycosuria almost inevitably leads to albuminuria in time. Pavy regards it as the result of irritation of the kidney. As long as it does not cause a rise of blood-pressure, cardiac hypertrophy, or other

evidence of arteriosclerosis, one need not trouble very much about the albuminuria. The treatment is merely that of the glycosuria.

The condition of the vascular system and the diacetic reaction will be a better guide than the amount of the sugar compared with the amount of albumen. The appearance of casts in the urine of a diabetic should, however, always be regarded as serious, and possibly prognostic of coma.

Treatment.—Having eliminated, as far as our present methods will allow, any gross disease of organs which may be associated with glycosuria, the ideal to be aimed at is regulation of the diet to a point at which both sugar and diacetic acid are absent from the urine. In a sense these aims are antagonistic, for it is the deprivation or non-utilization of the carbohydrates that causes the acetonuria. I would prefer the patient to pass sugar rather than diacetic acid, for the latter implies starvation, if not intoxication. No one to-day would think of putting the patient on to a very restricted diet all at once; to do so would be to court the danger of coma. The restriction should be quite gradual, and the urine tested at frequent intervals with ferric chloride for diacetic acid. Even though in a severe case we are unable to render the urine free from sugar, we can probably find a point to which the intake of carbohydrates can be raised without increasing the glycosuria while diminishing the acetonuria. This is the best point at which to maintain the patient's metabolism, for even if further restriction produces a

fall in the amount of sugar, it is not beneficial if it causes a return or an increase in the acetonuria. It may be asked why it is necessary to diminish the glycosuria at all if it is merely a symptom of the perverted metabolism. The answer is, that damage to the sugar-forming apparatus appears to be partially recovered from under physiological rest, while carbohydrate excess seems to increase the damage, and that the complications, apart from coma, depend upon the hyperglycæmia. I do not intend dealing with the details of treatment; I merely wish to call attention to certain principles which should guide us.

The sugar is estimated from a twenty-four-hour specimen while on an ordinary diet, and diacetic acid is tested for. If it is present, we know that we have a severe case to deal with.

The next step is to cut off the sugar in the diet, but not the starch at present. If sugar is still found in the urine, the condition is definitely pathological.

Now the starches are cut off gradually; if the urine is not free from sugar in a week from the giving of a strict diet, and if the acetone bodies make more than a transitory appearance, the case must be labelled diabetes.

Since almost all diabetics have some degree of tolerance for carbohydrate, and since total deprivation of carbohydrate will lead to acetonuria in anyone, it is important to determine as accurately as possible what that degree of tolerance is in the case under consideration. For this purpose some standard diet is neces-

sary of known carbohydrate content. The following is the one suggested by von Noorden:

Breakfast.—Coffee or tea, with 1 to 2 tablespoonfuls of thick cream, 6 ounces; hot or cold meat (weighed after cooking), 3 ounces; butter; two eggs with bacon; white bread, 2 ounces.

Lunch.—Two eggs (cooked as desired, but without flour); meat, about 6 ounces; vegetables, such as spinach, cabbage, cauliflower, asparagus, prepared with broth, butter or other fat, eggs or cream, but without flour; cheese and butter, 1 ounce; two glasses of light wine; one cup of coffee, with 1 to 2 tablespoonfuls of thick cream; white bread, 2 ounces.

Dinner.—Clear meat soup (with eggs or vegetables); one or two meat dishes, with vegetables, salad of lettuce and tomatoes; wine; no bread.

Drinks.—One or two bottles of aerated waters.

If this diet, which contains about 100 grammes of carbohydrate, does not cause any glycosuria, then the bread is gradually increased until sugar appears. If sugar does appear on this test diet, it may be continued for a few days till the sugar is constant, and the bread then diminished.

We can then assist the patient to reach as high a 'toleration point' as possible by (1) selecting those carbohydrates he can utilize and those proteins which least excite sugar production; (2) studying the effect of exercise on the excretion of sugar and regulating it accordingly; (3) diminishing the production of acetone bodies.

1. Failure to utilize carbohydrates is rarely absolute, and it is our first duty to find some form of starch which can be assimilated. Some years ago von Noorden advocated the use of oatmeal, and it is certainly true that many diabetics can take this well; it can be given in the form of porridge, gruel, or oatcake made without flour or sugar. Some patients appreciate this relaxation of the diet; they often tolerate potatoes fairly well. Potato cakes can replace bread to a certain extent, and 20 to 50 grammes (5 to 12 drachms) of fruit sugar (lævulose) can sometimes be assimilated if cautiously given in divided doses. If more is given than can be consumed by the tissues at once, it will be stored as glycogen and subsequently converted into dextrose. Its cost, however, is prohibitive, except for wealthy patients or in emergencies, such as threatened coma. I have seen striking benefit from its use. Artichokes are rich in inulin, which breaks down into lævulose. This is a cheaper method which sometimes helps.

Wheat starch seems to be the form of starch least tolerable to the diabetic, and the abiding difficulty is to find a satisfactory substitute for bread. As Osler says: ' Of the gluten foods, many are very unpalatable, others are frauds.' Under the present system of more moderate restriction of the carbohydrates, we need not insist, as a routine, on a pure gluten bread, and the Brusson-Jeune rolls, which are a mixture of gluten with some starch, are convenient and palatable; but even then I have found it advisable to intercalate some days on which a gluten or protene bread is given.

The second point in the control of the glycosuria is the influence of meat proteins in exciting it. This, which is insisted on by von Noorden, is often overlooked, and the patient is allowed to take meat freely. As a matter of fact, he can often take a vegetable diet, which must contain a good deal of carbohydrate, better than he can manage a carbohydrate-free diet with abundant meat. It may be that the carbohydrate fraction of the meat protein is not well borne, but more probably it is due to the stimulating effect of the meat on tissue metabolism. Von Noorden finds that the order of toleration is meat proteins least, then casein, next cooked eggs, and finally vegetable proteins, particularly glidine, best of all. The best scheme appears to be to alternate days of carbohydrate-free diet with days of oatmeal diet, and with days on which little beside eggs and vegetables are taken. Fast days, with rest in bed, may also be intercalated. I will give one or two examples of such diets, prefacing them with the remark that every diabetic is a law unto himself in the matter, and that careful investigation is necessary to find a scheme that suits each case.

Vegetable, Egg, and Oatmeal Scheme.—In the course of an ordinarily restricted diet a week of the following diets is introduced:

(1) For two days a diet of lettuce, cabbage, spinach, veal broth, three eggs, butter, two lemons for lemonade, coffee.

(2) For three days a diet of 8 ounces of oatmeal, as porridge or oatcake, 4 ounces of butter, five eggs, two lemons, and coffee.

(3) Two days of (1) again.

At the recent International Medical Congress von Noorden gave several other examples, of which I select one:

Three weeks of restricted diet (*i.e.*, no carbohydrates), with the addition of 60 grammes (approximately 2 ounces) of bread.

One vegetable egg day (*vide supra*).

One fasting day; only weak tea, lemon squash or whisky and soda (in suitable cases) are allowed, with rest in bed.

One vegetable egg day.

Four days of restricted diet alone.

The same scheme begins anew.

A marked increase in tolerance often follows. I have chiefly used the former of these schemes, and have noted distinct improvement, the urine becoming quite free from sugar in some cases—at any rate, for a time. If such a course seems too drastic in an individual case, it is still advisable to intercalate days when only oatmeal, eggs, green vegetables, plasmon, and glidine are taken.

2. Carefully regulated exercise usually benefits mild cases. Except on fast days or when necessitated by complications, even severe cases should not be confined to bed, as this seems to increase the liability to coma.

3. The control of acidosis is dealt with in the next chapter.

Though drugs may help to control acidosis, they have but little effect in preventing glycosuria. In so far

as they have any effect, we are entirely ignorant of the way in which they act, and therefore they do not really come into our present discussion. The general consensus of opinion seems to be that codein is the most effective in the severer cases, salicylate or aspirin in the milder cases. Personally I have never observed any benefits that could be ascribed to any other drugs. A great objection to the salicyl groups of drugs is the way they mask the important diacetic reaction, since the urine will now give a deep purple colour with perchloride of iron.

If it be objected that I have not succeeded in drawing a sharp line of distinction between the cases of mild glycosuria and severe diabetes, my plea must be that Nature has not done so; it is all-important to realize that a carbohydrate debauch may precipitate a mild and amenable case once and for all into the severe and intractable category, while systematic efforts to raise the level of tolerance may be rewarded by an apparently severe case becoming much milder in type.

CHAPTER IX

ACIDOSIS AND ACID INTOXICATIONS

It has long been known that diacetic acid appears in the urine, and acetone in the breath of a diabetic patient who is progressing unfavourably. In fact, its presence is often a better gauge of the patient's condition than the amount of sugar in the urine. But it is now recognized that this symptom appears in many other conditions, such as the recurrent vomiting of children, the pernicious vomiting of pregnancy, broncho-pneumonia, fevers, carcinoma of the digestive organs, rectal feeding, and after anæsthetics.

What general significance is to be attached to a symptom occurring under conditions apparently so diverse?

I. The Significance of Acidosis.

Acetone comes from the decomposition of diacetic acid, which is certain to be found in the urine if more than $\frac{1}{2}$ gramme of acetone is being excreted in a day.

The odour, variously compared with that of hay or of apples, is due to diacetic acid rather than to the acetone, which has a more penetrating odour.

It follows that the recognition of the diacetic acid in the urine is of greater importance than the detection of acetone, its decomposition product. On the addition of ferric chloride, a claret colour results, which (unlike the somewhat similar colour seen on addition of this reagent to the urine of patients taking salicylates or carbolic acid) does not appear if the urine has been previously boiled. A more sensitive test for diacetic acid is to add a few drops of a freshly prepared solution of sodium nitro-prusside to the urine, and then pour some strong solution of ammonia on the top. A magenta-coloured ring appears at the line of contact, and diffuses upwards. As shown by Rothera, the addition of crystals of ammonium sulphate makes the reaction still more sensitive. This test was formerly thought to show the presence of acetone till Hurtley proved its real significance.

Diacetic acid in its turn is derived from β-oxybutyric acid. There is no convenient clinical test for this body,* but it is probably present when the diacetic reaction is well marked. The chemical changes involved are simple. β-oxybutyric acid yields diacetic acid by oxidation, while diacetic acid is converted into acetone by the loss of CO_2; thus

$CH_3\,CHOH\,CH_2\,COOH$ = β-oxybutyric acid.
$CH_3\,CO\,CH_2\,COOH$ = Diacetic acid.
$CH_3\,CO\,CH_3$ = Acetone.

* After fermentation to remove the sugar, the concentrated urine is distilled with strong sulphuric acid, and the distillate examined for crystals of α-crotonic acid. β-oxybutyric acid is also lævorotatory.

It is quite probable that β-oxybutyric acid is a normal metabolic product, but diacetic acid would appear to be the point of divergence between the healthy and abnormal processes. The appearance of this abnormal acid constitutes *acidosis*. Its immediate precursor is a fatty acid; what is the source of that fatty acid?

The sudden and complete withdrawal of carbohydrates from the diet of a diabetic patient is known to be dangerous. It is followed by nausea, vomiting, loss of weight, the odour of acetone in the breath, the presence of diacetic acid in the urine, and a great increase in the amount of ammonia in the urine. Though the total amount of nitrogen is not altered, the ammonia is greatly increased. Signs of coma may also occur. In one case it is recorded that the ammonia increased from 7 to 29 per cent., and that the blood also became less alkaline. Then the patient was given more carbohydrates, and these symptoms disappeared. A great improvement took place in the general condition of the patient, including the disappearance of the smell of acetone in the breath and the diminution of the ferric chloride reaction of the urine, although there was no marked change in the amount of sugar excreted in the urine.

It is therefore clear that these bodies do not come from carbohydrates, because carbohydrates diminish the amount of them in the urine. Do they come from protein or from fat? Both views have been held, but protein cannot be the main source, for the

excretion is not accompanied by a proportionate increase in the excretion of nitrogen and sulphur.

It is possible, however, that some of the fatty acid groups in protein, such as leucin, can give rise to acetone bodies. It has been shown that leucin increased the output of both acetone and β-oxybutyric acid in a diabetic and in a normal man deprived of carbohydrates.

But it is to the fat chiefly we must look as the source of the acetone bodies.

Geelmuyden and others produced acidosis in healthy persons by a fatty diet. In one case the sole diet daily for five days was 250 grammes of butter, 200 grammes of oil, and a little wine. β-oxybutyric acid, diacetic acid, and acetone were then as abundant in the urine as in the severest cases of diabetes, while 37 per cent. of the total nitrogen was in the form of ammonia.

The Element of Starvation.—Anyone can produce acidosis by starving himself. In some diseases associated with acidosis the element of starvation is obvious—for instance, in carcinoma of the digestive organs, certain febrile conditions, and rectal feeding. A wasting diabetic is being starved also from inability to metabolize carbohydrate.

Of all the tissues, the fat loses most in starvation, the more noble organs being fed at the expense of the less essential ones. To effect this, the fat must be broken down, in the course of which fatty acids would be set free. If fat has been got rid of previously,

acetonuria is not so marked a feature of starvation, while a fatty diet accentuates it.

An easily assimilable food, such as dextrose, leads to a prompt diminution or disappearance of the acetone bodies. That the acetonuria of febrile conditions could be largely inhibited by supplying the wasting tissues with carbohydrates von Noorden proved as follows: In two cases of typhoid fever, he gave patient A a diet with very little carbohydrate in it, and patient B one with plenty of carbohydrate. A had a marked diacetic reaction, and B only a trace of acetone. After a few days the diet was reversed, with the result that the former showed only a trace of acetone, and the latter a well-marked diacetic reaction. Meyer has made similar observations on children suffering from various acute infectious fevers. Halpern has recorded the case of a man with an œsophageal stricture, whose only food for twenty-six days was 30 grammes of grape sugar *per rectum*, yet his urine contained no acetone or diacetic acid. The quantity of carbohydrate sufficient to abolish the acetone bodies from the urine does not supply so much energy as was being provided by the fats, so that the carbohydrate does not merely act as a fat-sparer.

The Element of Defective Oxidation.—Oxygen starvation can produce a similar effect to deprivation of carbohydrates. Thus in mountain-sickness, in which deficiency of oxygen pressure is the exciting cause, acidosis occurs. Oxygen starvation is obviously at work also in broncho-pneumonia.

Von Noorden correlates these factors by attributing the rôle of carbohydrates in preventing acidosis to their relative abundance in oxygen, which is drawn upon to complete the breakdown of the tissues into CO_2 and water. In its absence the less completely oxidized fatty acids appear.

I would suggest a slightly different and rather simpler view. Verworn thinks it probable that the oxidation of the tissues is carried out by non-nitrogenous groups of a carbohydrate nature, which therefore contain aldehydes.

In the absence either of sufficient oxygen or of aldehyde molecules to which the oxygen could attach itself, defective oxidation of the tissues must occur. Acidosis, therefore, is a sign of incomplete oxidation due to interference with either factor. In Rosenfeld's phrase, fats are consumed in the fire of the carbohydrates.

Other substances besides carbohydrates, however, appear to be able to do this. Alcohol, tartaric, citric, and glutaric acids are all capable of diminishing the output of the acetone bodies. Hurtley and Bainbridge found that 20 grammes of citric acid daily had a marked effect. The benefit of citrates in diabetic acidosis is generally regarded as due to their neutralizing the abnormal acids by becoming bicarbonates in the blood. But evidently this is not the only way in which they act, and this explanation would not apply to alcohol.

Now, the organic acids of disordered metabolism

have to be excreted by the kidney, because they are not oxidized to CO_2. Carbon dioxide can be removed without loss of bases, whereas unburnt organic acids must be excreted as neutral salts. This may be done by combining with ammonia or with fixed alkali. Acidosis, therefore, may be due to a shortage of fixed bases as well as to an excess of acids. In diabetes there is a prolonged drain on the calcium and magnesium salts, which must be a factor in inducing acidosis.

Acidosis and Acid Intoxication. — We must distinguish between acidosis, in which these organic acids occur in the blood and urine, and acid intoxication, where, in addition, toxic symptoms make their appearance. Are these symptoms produced by the fatty acids *per se*, or is the presence of these acids merely another symptom of perverted metabolism?

The acids are not themselves directly toxic. Given to man or animals, they do not even produce acetonuria. But they might produce toxic results simply because they are acid, and thus upset the alkalinity of the blood,* diminishing its power of taking up CO_2, and leading to internal asphyxiation of the tissues. This will actually occur if animals are repeatedly injected with acids, though carnivora have considerable power of neutralizing the acids by producing ammonia from their proteins.

* Alkalinity is here used in the accepted sense of 'titration alkalinity,' which indicates the power of the blood to neutralize weak acids. In the strictest language of modern physical chemistry, blood is neutral, having no excess of hydroxyl atoms.

But experimental acid intoxication is, perhaps, not strictly comparable to the acid intoxication of disease. Thus, though in diabetic coma the alkalinity of the blood is usually reduced, this is not invariably the case. According to Pembrey, Spriggs, and Beddard, the low percentage of CO_2 in the blood of comatose diabetics is not so much due to the blood being unable to combine with it (for outside the body the blood may still be able to take up a normal amount of CO_2), but is rather the result of the exaggerated respiratory movements. However, the total amount of abnormal acids excreted in the urine will be a better guide to the degree of acid intoxication than the composition of the blood at any one time, since the kidneys will attempt to keep the composition of the blood constant. Again, the exaggerated respiration is probably due to excess of CO_2 in the respiratory centre, and indicates some difficulty in getting rid of it.

Acid intoxication may be said to occur at the point where the body fails to cope with the tissue disintegration, of which the abnormal acids are a sign, or to compensate for the drainage of alkaline bases.

Tissue degradation, or autolysis, is brought about by intracellular ferments whenever the food-supply is insufficient for the needs of the organism. Consequently, the nobler organs can live at the expense of the others by utilizing the products of this ferment action.

Schryver has shown that this autolysis proceeds much more rapidly in fasting than in well-fed tissues.

The products of autolysis fall into two groups, amine bodies and non-nitrogenous acids.

In well-nourished animals the excess of ammonia, which is always present from protein disintegration, will neutralize the acids, the resulting ammonium salts being converted by the liver into urea. But in starvation, the fats being chiefly drawn upon, the non-nitrogenous acid groups will be formed in excess. These will appear in the urine as oxybutyric and diacetic acids.

If acidosis as a symptom of tissue disintegration occur without acid intoxication, it is because the protective ammonia formation is sufficient. When once this becomes insufficient, acid intoxication will result.

To recapitulate, acidosis is the result of increased katabolism of fat itself, or of the fatty-acid groups in protein. This will occur in any starving tissue, but particularly if oxidation be deficient, because then the final breaking down of the fat into water and CO_2 does not occur. Deprivation, or non-utilization, of carbohydrates is specially likely to cause acetonuria, both because the tissues are being starved, and because the process of oxidation is apparently closely connected with the carbohydrates. If the increased katabolism of fat is great enough to cause acid intoxication, the condition becomes much more serious. Acid intoxication may result either from abnormal production of acids or from deficiency of bases.

II. Symptoms associated with Acid Intoxication.

(*a*) *In Diabetes.*—The cardinal symptoms have already been dealt with, when considering the effect on a diabetic of sudden deprivation of carbohydrates. But milder manifestations of this sort are not infrequent in the more amenable type of diabetes. If 'bilious attacks,' accompanied by some drowsiness, occur, they will usually be found to be associated with the appearance of acetone and diacetic acid in the urine, though these bodies may have been previously absent.

The symptoms of diabetic coma are too well known to need restatement. It is a curious fact that there may be a decided drop in the excretion of acetone bodies just before and during the coma, which shows that the pathology of the condition is not yet fully explained.

(*b*) *In Recurrent Vomiting.*—In 1882, Gee described cases of fitful and recurrent vomiting of unknown causation in children. Later observers noted acetone in the breath, urine, and vomit. Diacetic acid and oxybutyric acid have also been found when looked for. The analysis of fifty-five cases by Batty Shaw and Tribe gives the following clinical features: The cases usually occur between three and eleven years of age. The frequency of the attacks is very variable, a common interval being three months. There may be a prodromal period, in which dyspnœa, sighing respirations, offensive breath, choreic movements, and general

restlessness have been noted. The tongue may either be coated or clean. Then vomiting begins, without nausea, and usually without gastric pain, all food is rejected, and towards the end of the attack bile appears, sometimes even blood. Constipation is common. The attacks may last only a few hours, but the average duration is five or six days. It is the rule for fever to occur during the attacks of vomiting. Wasting is often a very marked symptom. In later life these attacks are sometimes replaced by migraine, but they tend to disappear when puberty is reached. Three of the fifty-five cases were fatal. A mild degree of such a condition is, I believe, quite common in children, and I would venture to suggest that 'biliousness,' which, as Gee says, is a real state, a very common state, but a state that is little understood, is also of this character. Probably the liver is put out of work by some toxin, and in many cases this toxin may be due to the *B. coli* which has invaded the biliary passages, or to the *B. aminophilus*, which can form poisons from histidene. This would explain why the prompt use of a mercurial purge may ward off an attack. When once the liver fails to do its work, the tissues are starved, and, in their autolysis, produce these abnormal acids. The vomiting accentuates the condition by increasing the starvation and the loss of saline bases.

(*c*) *In the Pernicious Vomiting of Pregnancy.*—Though the pernicious vomiting of pregnancy may be due in some cases to mechanical causes, such as displacement

of the uterus, and in others to neurotic causes, there remains a more serious group in which a toxæmia is responsible. In these toxæmic cases, necrosis and degeneration of the central portion of the liver lobule, and necrosis of the excretory portions of the kidney, have been found by Whitridge Williams. He found also a striking increase in the percentage of nitrogen, eliminated as ammonia, which, compared with the total nitrogen of the urine, amounted to 16, 32, or even 46 per cent., instead of the normal 3 to 5 per cent. He suggested that this might be due either to failure of urea formation in the liver, or to the attempt to neutralize acid intoxication.

Dr. Helen Baldwin found, in such a case, that the urine yielded a marked reaction for acetone and diacetic acid, but no sugar. The patient's condition was so serious that labour was induced. After this the abnormal acids diminished, until only acetone was found. On the tenth day after the induction of labour there was a return of severe headache, nausea, and vomiting, and it was noteworthy that, on this day, diacetic acid was again found in the urine. After this recovery was uninterrupted.

But Williams' interpretation of these facts is open to several objections. A very small proportion of the liver substance is sufficient to carry out the conversion of ammonia into urea. Extensive necroses have been produced experimentally in the liver without raising the percentage of ammonia.

In starvation from any cause, the percentage of

ammonia increases, mainly because of diminished urea excretion, which must occur since so much of the urea is derived directly from the nitrogenous food. Now, the absolute amount of ammonia nitrogen in Williams' first case during the vomiting was 1·44 grammes, while a month after labour had been induced it was 1·21 grammes. These differences are not so great as those observed by Cathcart in a professional faster, in whom the ammonia nitrogen was 0·6 gramme before and 1·4 grammes during the fast.

Again, the total nitrogen output in Williams' cases was lower than that found by Cathcart in his fasting man and that which I have found in cases of hæmatemesis receiving saline enemata only.

When ammonia is expressed in percentages, these important facts are obscured, and an ammonia coefficient reaching to 32 or 46 per cent. is apt to acquire an undeserved significance.

Leathes puts it very fairly when he says: 'Before it can be safely maintained that these high figures are a sign in themselves of a toxæmia that is likely to prove fatal unless the most active measures be taken, it is necessary to prove that they are not sufficiently accounted for by some of the attendant circumstances of the patient's condition—the low nitrogen content of the absorbed food, the imperfect nutrition due to the incessant vomiting, the loss of alkali in the vomit, aggravated possibly by the requirements of the fœtus.' In other words, the high ammonia coefficient may result from simple starva-

tion, rather than from an attempt to neutralize acids.

(*d*) *In Gastro-intestinal Acetonuria.*—I saw a good example of this in a lady, aged twenty-four, who consulted me for rapid wasting with marked constipation and occasional vomiting. She only weighed 5 stone 6 pounds, and all the ordinary causes of wasting could be excluded. In a fortnight she had lost 2 pounds more. Diacetic acid was present in the urine, but no sugar or albumen. Then membranous casts were found in the stools. I ascertained that she had been taking an extraordinary diet, containing very little nourishment—large quantities of beef-tea, mushrooms, and extractives of all sorts. The treatment was simply to regulate the bowels, and to give her a plain but liberal diet, with alkalies before meals, and 20 grains of citrate of potassium three times a day. The diacetic acid soon disappeared, and the patient rapidly gained weight—1 stone in six weeks. Two years later I heard that she was quite well.

(*e*) *In Broncho-pneumonia.* — Garrod associates drowsiness, torpor, and vomiting with the presence of diacetic acid in the urine.

The principal symptoms, then, which seem to be commonly associated with the various forms of acidosis are wasting, vomiting, drowsiness, and coma.

Post-Anæsthetic Acidosis. — That death might follow the delayed action of chloroform was first suggested, so long ago as 1850, by Casper. In this country Leonard Guthrie drew attention to the condition in

1893, and much interest and discussion has been aroused. Other anæsthetics besides chloroform may be responsible.

Twelve hours or so after the anæsthetic the patient (usually a child) suffers from profuse and repeated vomiting, the vomiting eventually resembling the dregs of beef-tea. Sometimes there is a preliminary period of restless excitement and delirium.

This is followed by drowsiness, apathy, and unconsciousness, deepening to coma. Death usually occurs about the fifth day, but sometimes later, from gradual or sudden cardiac or respiratory failure. Pyrexia is not the rule, though the temperature may be very high just before death. The pulse becomes very rapid. Albuminuria with casts is common. Furthermore, there is a smell of acetone in the breath, while diacetic acid is found in the urine. It will be noted that these symptoms resemble in essentials the features of other acidoses; but the abnormal acid was only looked for at first where something went wrong after anæsthetics.

It is now generally agreed that diacetic acid is often present in the urine after anæsthetics, and not uncommonly before. Frew has shown that in children the mere change of diet accompanying admission to hospital is sufficient to induce acidosis. As the hospital diet is rich in carbohydrates, it is not due to starvation but to the fact that the child apparently takes three days to adapt its digestion to the change. Now the majority of children that are admitted for operation receive their first anæsthetic within three

days of admission—that is to say, while acidosis is already present. In addition to this, tradition demands that the patient should be starved both before and after operation, and that an acute diarrhœa should be induced. In short, everything is done to induce acidosis, and then a toxic vapour is given, and an operation is performed which further lowers vitality. It is curious that toxic symptoms do not occur more frequently. Possibly the concentration of the anæsthetic vapour has something to do with it, a high percentage having a more injurious effect on the protoplasm of the liver than a low one.

The most striking change noted post mortem is fatty degeneration of the middle zone of the lobules of the liver, with necrosis of the central part. To the naked eye the liver appears large and canary-yellow in colour. This change can occur very rapidly. Thus Telford saw a liver to be normal while performing a gastro-enterostomy; toxic symptoms followed, and at the post-mortem the liver was slightly enlarged, bright yellow and loaded with fat. This is a point against Guthrie's view that the anæsthetic is merely the last straw, acting on a previously fatty liver, to which feeding up with fat may have contributed. The anæsthetic has been the last straw indeed, but by converting a previous acidosis into an active intoxication.

All anæsthetics are solvents of fat, and the breaking down of such dissolved fats could give rise to excess of fatty acids. But many very fat people have been

exposed to long administration of chloroform without these after-effects.

Why should fat in the liver behave so differently to fat in other parts ?

Fat in the liver may be obvious as the result of sepsis, broncho-pneumonia, phthisis, rickets, profound anæmias, and phosphorus-poisoning. But the amount of obvious fat is not an accurate criterion of the total fat in an organ. Thus, as Leathes points out, the fatty nerve sheath does not stain with osmic acid if it is prevented, by fixing agents, from undergoing the changes which would otherwise slowly occur. But degenerated nerves contain free fats, which can at once be demonstrated despite fixing reagents. In the same way, all the fat normally present in the heart, kidneys, or liver, does not give the characteristic reactions, or even yield to fatty solvents, while after degeneration it does so readily. Thus it happens that an obviously ' fatty ' organ sometimes actually contains less fat than normal.

Again, Rosenfeld has shown that ' fatty infiltration ' of the liver may be really due to transference of fat from other parts. The condition may be fairly called one of ' fatty congestion.' Phosphorus and diphtheria toxin act similarly by retarding the normal reaction of the cells, probably by inhibiting the oxidases. The liver normally appears to receive saturated fats, which it converts into unsaturated fats, thereby enabling their final oxidation to be carried out more easily. If it be unable to do this, fatty infiltration of the organ must occur.

The poisoned liver appears to be unable to oxidize proteins properly, and fats hardly at all. Therefore, as soon as it has used up its scanty store of carbohydrate, its starving condition causes a breakdown of protein and a transference of fat to it; yet the fat on arrival there is useless. This transport of fat may be prevented by feeding with dextrose, which will prevent starvation of the damaged liver.

The term 'fatty liver,' therefore, implies that the vital reactions of the liver have been so altered that it can deal neither with its own fat nor with the fat reaching it from elsewhere. Its own fat is now present in simple forms, which can be readily dissolved. The conclusion to which we are led is that, while anæsthetics and the preparation for them may cause acidosis, they will not cause toxic symptoms, unless the liver is thrown out of gear at the same time, perhaps by inhibition of the oxidases. A diseased liver will naturally be more easily affected than a sound one. Deprivation of readily assimilable carbohydrate is the most effective way of inducing the catastrophe of post-anæsthetic poisoning.

III. Treatment of Acid Intoxication.

The indications for treatment are—

1. To prevent further formation of fatty acids as far as possible. Broadly speaking, this will be accomplished by promoting the assimilation of carbohydrates.

2. To break the vicious circle in autolysis, and

combat acid intoxication by neutralizing the acids already formed, or by supplying the deficient bases.

By what methods can we put these indications into practice?

(*a*) *In diabetes*, it is no use pouring in carbohydrates which cannot be utilized. The difficulty has arisen from the failure to metabolize carbohydrates; but this failure is seldom absolute.

In the chapter on Glycosuria and Diabetes it was pointed out that lævulose, artichokes, potato, and oatmeal are the forms of carbohydrate most likely to be assimilated, and careful trial must be made as to which of these is most effective in diminishing acidosis without increasing glycosuria. If coma is impending, however, the reduction of acidosis becomes the first consideration. Eight ounces of oatmeal in the form of gruel should be taken in the day, together with plenty of butter, and in severe cases von Noorden restricts the diet to this for the time. As previously stated, the capacity of a diabetic is limited to the amount which his tissues can consume on the spot, and this probably will not exceed 20 grammes (5 drachms) in the day.

While bearing in mind the dangers of the alcohol habit, it is nevertheless often advisable to give alcohol to the extent of about an ounce of the pure spirit in the day, because of its being able to replace carbohydrates to a limited extent in metabolism. Malt liquors, sweet wines, champagne, and liqueurs will naturally be avoided.

In order to neutralize these acids, alkalies should be

given with a free hand whenever the ferric chloride reaction appears in the urine. Spriggs has given a valuable guide to their use by pointing out that if 2 drachms of sodium bicarbonate be given to a normal individual, the urine becomes alkaline and remains so for twenty-four hours. But if excess of acid is being formed, this amount is insufficient, and the amount of bicarbonate that can be taken without producing neutrality or alkalinity of the urine may be regarded to some extent as a rough measure of the degree of acid production. A more accurate measure is the amount of ammonia in the urine, which can be quickly estimated by the formalin method. In severe cases it may be impossible to make the urine alkaline. If the condition improves under treatment, the urine will become alkaline, and the amount of bicarbonate may be gradually diminished without a return of the acid reaction. This alkaline treatment should never be omitted in severe diabetes.

I have usually given citrate of potash as well as bicarbonate of soda, because it is not neutralized by the gastric juice, and it becomes bicarbonate in the blood, which is where the alkali is most needed. It can be given in 45-grain doses, and is particularly suitable in those milder cases of diabetic acetonuria in which some drowsiness and ' bilious ' symptoms are present.

But we know now that the advantage of citrates does not end here, since citric acid appears to have a marked effect in diminishing the production of acetone

bodies by enabling the metabolism of fat to follow its normal course.

It is not sufficient to supply the body with bicarbonate of soda, as is generally done; other bases should be given also, especially as in diabetes there is a drain on the calcium and magnesium.

A mixture such as this—

Sodii bicarb.	ʒi.
Pot. citrat.	gr. xxx.
Calcii carbonatis	gr. iii.
Magnesii carbonatis	gr. iii.
Aq.	ad ʒi.

Tertiis horis

is of more service, because the amount of K_2O excreted daily is one-half that of the Na_2O, while the CaO and MgO are each one-twentieth of the amount of the soda.

Much may be done towards preventing coma by careful attention to the acidosis. A rise in the ammonia output to 4 grammes a day is very ominous. As soon as coma threatens, the rectum should be cleared out, and 3 per cent. of sodium bicarbonate with 4 per cent. of lævulose given by drop enema until about $1\frac{1}{3}$ litres of fluid have been administered. If, in spite of this, coma supervenes, at least a pint of alkaline solution should be infused intravenously. It is customary to use 2 per cent. of bicarbonate of soda in normal salt solution, but it would be better to give the other bases as well. A return of consciousness may follow, but unfortunately coma soon reasserts itself. Nor is this surprising, for at present we cannot strike

at the root of the mischief. But there are obvious advantages in even such a temporary rally, in which the reason and the powers of recognition are restored.

The general rule is that the total amount of alkali should not be more than about 1 ounce a day. Beyond this amount it is thought to have a depressant action on the heart, but I think that this danger is less than that of acid intoxication, and that the dose need not be thus limited. In a condition which we believe to be associated with deficient oxidation, to which the characteristic air hunger also points, inhalations of oxygen might seem reasonable. But since the cell lacks oxygen because a link is missing, not much can be expected from them. And it remains true that, in diabetic coma, ' the duration of life is to be measured by hours rather than days.'

(*b*) *In the Recurrent Vomiting of Children.*—To ward off attacks, prodromal signs should be noted—white stools, offensive breath, some change in complexion, usually indicative of what are called ' bilious attacks,' and the presence of abnormal acids in the urine—then mild aperients and easily digestible foods are indicated. Barley-water is usually tolerated. Small doses of grey powder or calomel should be given, also bicarbonate of soda, up to 3 drachms in the day. Normal salt solution *per rectum* is useful. I would suggest that arrowroot might be employed, on the principle that the abnormal acids are checked in their production by the administration of carbohydrates.

(*c*) *In the Pernicious Vomiting of Pregnancy.*—Whitridge Williams recommends that when the amount of nitrogen in the form of ammonia rises from the normal 3 or 5 to 10 per cent. of the total, labour should be induced. We have already seen, however, that this ammonia coefficient may be a fallacious guide. The condition of puerperal eclampsia differs from this, because the total amount of nitrogen excreted is diminished, and the proportion of ammonia remains constant. But some observations by Longridge suggest that the same general line of treatment is applicable. He noticed a diminution of alkalinity of the blood in eclampsia, but he did not state whether this was due to the presence of diacetic acid. He gave citrates with the object of bringing up the diminished alkalinity of the blood to normal. Sugar was given by the mouth and rectum, 'in order to replace the glycogen in the liver, without which that organ could not exert its antitoxic functions.' But a simpler explanation of the beneficial action of carbohydrate is its power of preventing the formation of these abnormal acids.

(*d*) *In Post-anæsthetic Poisoning.*—(1) Before operation on even fat and apparently healthy children careful inquiry should be made as to the history of so-called 'bilious attacks,' which may in reality be those of acidosis (Guthrie). (2) Where possible, operation on a child should be delayed until it has been accustomed to the altered diet in hospital. The urine should be examined for diacetic acid, and, if present, alkalies should be prescribed. (3) Both

starvation and fright cause acidosis. Four hours' fast for children before operation is too long. Saline enemata containing 2 to 5 per cent. of dextrose should be given after the lower bowel has been cleared, two hours before and immediately after operation. The effect of fright cannot be altogether controlled, but may be diminished by preventing starvation. Should symptoms of acid intoxication occur despite these precautions, it must be treated as in other cases. Dextrose must be got into the system somehow, and Beddard recommends that if it cannnot be retained in the stomach, it should be given by continuous rectal infusion of a 10 to 20 per cent. solution, or even by infusing intravenously a 6 per cent. solution. I should prefer 5 per cent. for rectal irrigation as less likely to irritate the bowel. Once post-anæsthetic vomiting is established, bicarbonate of soda and other alkalies must be given freely to neutralize the acids already formed.

Such, then, are in general the lines on which acidosis and acid intoxication must be approached. Though advance has been made, we cannot expect complete success until we have a much clearer conception of the internal metabolism of the cell, a subject on which our knowledge at present is mainly a series of 'guesses and gaps.'

CHAPTER X

INTESTINAL INTOXICATIONS

There are fashions in pathology, as in dress, and signs are not lacking that intestinal intoxications are coming in for a large share of attention. Most diseases of hitherto unexplained causation are now referred to this. It is such a fatally easy explanation that is it but human to yield to the temptation in face of perplexity.

Englebert Taylor well says that 'the progress of the auto-intoxication theory, like that of every other uncontrolled movement in practical medicine, is like the development of gossip in common life: the first person suggests that it might be so, the second states that it is so.'

Yet the subject is one of very practical importance. The alimentary canal is an open door for infection, and it is quite probable that many cases of chronic and indefinite invalidism depend upon intoxication by this route. Therefore, it is worth while to consider what is really meant by an intestinal intoxication, and what symptoms it might be expected to cause. We can then examine the evidence necessary to establish the

fact that intoxication has occurred, and inquire how far that fact is proven in some special cases. Progress cannot be made by haphazard reference to pyorrhœa and constipation, important factors though they be.

'The mucous membrane of the alimentary canal is pre-eminently an absorbent surface—it is constantly bathed in liquids swarming with bacteria.' The flora is both varied and extensive, yet how seldom does infection by pathogenic organisms or intoxication by saprophytes occur.

Probably microbes constantly invade the body from the alimentary canal, but are as constantly destroyed. Flexner has shown how frequently a terminal infection occurs when the vital forces of the body are exhausted. Metchnikoff compares the leucocytosis of digestion to the leucocytosis in certain infections, believing them to be due to the same cause—the resistance of the body to invasion. The comparison is at any rate suggestive. The body possesses three lines of defence against intestinal intoxications and infections: Firstly, the epithelial resistance; secondly, the bactericidal properties of the blood; thirdly, the antitoxic functions of the liver. Possibly the ductless glands, especially the thyroid, provide a fourth.

Gastro-intestinal intoxication might be conceived to result from—

1. Inorganic poisons—*e.g.*, lead.
2. Organic poisons—*e.g.*, cyanides, foreign proteins.
3. Intermediate products of digestion—*e.g.*, peptones, purins.

4. Products of putrefaction—*e.g.*, indol.

5. Products of abnormal pathogenic bacteria present in the intestine.

The first two do not concern us here. The reaction of the body against them differs in important respects from the method adopted against bacterial poisons. The neutralizing substances are normally present in the body, and are not specific, each of them combining with several poisons. Fromm points out that these reactions are few and simple, such as oxidation, reduction, hydration, dehydration, and methylation. The protective substances are also few, such as proteins, bile acids, glycuronic acid, etc. They are not the result of any special adaptation to meet a pathological condition. They are there as the result of normal metabolism; they have an affinity for various chemical substances, some of which happen to be poisons. If these enter the body, they are neutralized to some extent, though, as a rule, very incompletely. This is a very different reaction from the formation of highly specific immune substances against bacteria and their products.

Intoxication by Intermediate Products of Digestion.

Peptone is not the end-product of digestion, but the process is carried further to simpler amine bodies. As intravenous injections of proteoses and peptones will cause symptoms, it has been suggested that intestinal intoxications may result from absorption of these inter-

mediate products, the toxic effect decreasing with the decreased size of the molecule. But there is no definite evidence that such an absorption occurs.

Passing from the simple to the compound proteins, nucleo-proteins are credited with a toxic power on account of the purin bodies that they contain; but, normally, the liver has the power of destroying these to a large extent.

The importance of the distoxicating action of the liver is readily established. Dogs in which an Eck's fistula—*i.e.*, a communication between the inferior vena cava and the portal vein—has been made, showed toxic symptoms, especially after a meal of meat. In fact, the dogs came to recognize this effect of meat, and avoided it, living on foods which contained very little protein.

These experiments show that even in normal digestion the absorbed products are not sufficiently elaborated to be used by the tissues. A further step has to be taken by the liver, and this is one of the most important functions of that organ in metabolism. When in a disease we find an intermediate product of normal metabolism excreted in the urine, I think we must conclude that hepatic insufficiency rather than intestinal intoxication is the cause of the toxic effects observed. For the evidence of the toxic effects of such products is, to say the least, very doubtful.

Intoxication by Products of Putrefaction.

Whether digestion can be carried on aseptically is a purely academic question, since the opportunity never arises. The infant starts with a sterile alimentary canal, but speedily acquires bacteria therein, chiefly organisms derived from the skin of the mother's nipple. In the intestine of bottle-fed children there are many more organisms of the *Bacillus coli* class. The *Bacillus putrificus* begins to appear in childhood, and the flora of the intestine becomes large and varied.

Now, in putrefaction abnormal products of disintegration may be set free, and we must inquire into their responsibility for symptoms. The great seat of putrefactive change is the large intestine. Proteins putrefy, carbohydrates ferment, and to a certain extent these two processes are antagonistic. Fermentation may be useful to animals that eat a large quantity of uncooked vegetables, because the cellulose resists the ordinary digestive juices, so that until the cell-walls are dissolved by bacterial agency the contained foodstuffs are not available. This, however, is not much use in human beings; but fermentation plays another useful part in antagonizing putrefaction, which might lead to the development of more toxic substances. Putrefaction is the disadvantage of a large intestine, the advantage being that, by the absorption of water there, the bulk of the fæces is greatly reduced, so that the emptying of the bowel need not occur normally more than once a day. There is also less need for

drinking large amounts of fluids. According to Metchnikoff, the disadvantages outweigh the advantages, and, in fact, he looks upon old age as the result of chronic intoxication from the large bowel. The animals with a short colon are long-lived is, in effect, his conclusion; and it seems to be the opinion of some surgeons that it is better for a man to dispense with the services of his colon than to possess an indolent one. Yet we can hardly suppose that the colon would have appeared in evolution without the development of a compensatory protective mechanism. And we have evidence of its existence. Indeed, the evidence of intoxication by the products of the ordinary putrefactive changes in the intestine is quite inconclusive. Let us see what these changes are, and how far any of the resultant bodies can be incriminated. The mechanical factors involved have already been discussed in Chapter III.

Proteins undergo the most changes in putrefaction. Whatever the protein, it contains the same four groups, however different the representatives of those groups may be.

Mon-amino Fatty acids—*e.g.*, Leucin.	Hexone Bases —*e.g.*, Arginine.	Aromatic Bodies—*e.g.*, Tyrosin, Tryptophan.	Cystin containing S.
			SO_2

Putrefaction would seem mainly to affect the right-hand groups in this diagrammatic scheme—*i.e.*, the aromatic bodies and the sulphur groups. Tyrosin yields phenol compounds, while tryptophan yields

indol and skatol; the oxidized sulphur appears as sulphates, and the unoxidized as cystin.

The sulphates conjugate with the aromatic bodies in the liver to form ethereal sulphates which are practically harmless. These ethereal sulphates appear in the urine. Indican is one of them, being indoxyl-sulphate of potash. As this is readily detected in the urine by its striking colour reaction, much of the theory of intoxication by putrefaction centres around it.

The tests usually employed are—

1. To 2 inches of urine in a test-tube add an equal quantity of strong HCl and 3 drops of hydrogen peroxide (10 volumes per cent.); add $\frac{1}{2}$ inch of $CHCl_3$, and shake up thoroughly. If indican be present, the $CHCl_3$, when it has again sunk to the bottom, will be tinged blue. This is a very sensitive test.

2. A little ferric chloride may be used similarly with the strong HCl (Obermayer's test). It is best to precipitate phosphates first with lead acetate.

But we cannot conclude, simply from getting this striking reaction, that we are dealing with a case of intestinal intoxication. The ethereal sulphates are not themselves toxic, and even if they were, we cannot judge of their total amount by indicanuria alone, which only represents one of them. The amount of reabsorption will be also influenced by the rate at which the contents are passing along the canal.

There is normally very little indican and other ethereal sulphates in the urine of children and adolescents, but putrefactive processes are more abundant

in middle life. Indicanuria is common in students leading sedentary lives. Herter found that the body has the power of rapidly transforming considerable amounts of indol, since, even after injecting as much as ½ gramme into the femoral vein of a dog, he was unable to detect any in its blood.

Repeated administration of indol to rabbits causes loss of weight, among other symptoms. In man, taking considerable amounts causes headache, with indisposition for mental or physical exertion. The muscles respond as if fatigued. Herter suggested that if prolonged, this may lead to neurasthenia. In thirty-two cases of neurasthenia he obtained a marked reaction for indican twenty-one times, a slight or no reaction eleven times. He concluded that while indol is not a highly toxic substance, people with a persistently strong indican reaction invariably suffer from nervous or dyspeptic disorders, and that many with well-marked indicanuria have to live carefully to keep fit. He regarded those with soft arteries, little indican, or ethereal sulphates as ' candidates for old age.' Exceptionally there may be enough indican in the urine to form a blue pellicle on the surface without addition of reagents. The subjects of this condition are almost invariably badly nourished and in poor, almost precarious, health. But it is not desirable to single out indicanuria as the sole object of treatment, as it is linked to other intestinal conditions.

I would suggest that, whether such substances do or do not exert their toxic effect depends largely on

whether they are free, or whether there is sufficient sulphate for them to combine with, in which state they are harmless. In support of this, I may refer to a striking case described by Garrod. He examined the urine of a lady who for many years had applied a carbolic dressing to an ulcer on the leg. He reported that she was on the verge of carboluria. Her medical man proceeded to put this statement to the test by giving her 20 minims of carbolic acid internally. He had the satisfaction, at any rate, of knowing that he had obtained a correct opinion, for his patient promptly had a smart attack of carboluria! Garrod's opinion was based on the observation that almost all the sulphates were in the form of ethereal sulphates—*i.e.*, her power of neutralizing the toxic effects of phenol was taxed almost to the full. A little more and she was over the brink. Now, indol is closely related to phenol chemically. This points to two considerations: (1) When we test for indican, we are testing for just that part of the indol which has been rendered inert. (2) We may here have an explanation of the comparative failure of the phenol compounds as intestinal antiseptics. By combining with the sulphates they deprive the body of the power of rendering harmless those putrefactive substances of which they cannot altogether prevent the formation.

This may also be the explanation of the value of sulphates in the treatment of certain intestinal diseases; they are not only aperient, but also antitoxic in their action.

In fact, the ratio $\frac{\text{ethereal sulphates}}{\text{simple sulphates}}$ gives a much surer indication of the existence or approach of an intoxication by aromatic bodies than qualitative tests for indican.

Normally this ratio is 1 in 20 to 1 in 10. It is sometimes high when little indican can be found in the urine, and low in the presence of marked indicanuria. Mackenzie Wallis finds that indican tends to disappear on standing, so that it is important to examine the urine quite fresh; therefore indicanuria is at best rather a fallacious guide to the recognition of an intestinal intoxication, but its persistent occurrence suggests careful investigation of the digestive system for visceroptosis and the like.

The discovery by Barger and Dale of diamines set free by putrefactive changes, which raise blood-pressure, confirms the general impression that intestinal putrefaction is a factor in the rise of blood-pressure in later life.

The other two food-stuffs may be held almost guiltless as a cause of intestinal intoxication. In fermentative dyspepsia carbohydrates may give rise to oxalic acid, causing oxaluria; more commonly they are a source of lactic acid, which is antagonistic to putrefaction. Fats will produce fatty acids as a result of bacterial action, but these will not produce toxic symptoms. The fatty acids associated with acid intoxication in diabetes, for instance, are formed in the tissues, not absorbed from the intestine.

The case for the occurrence of an intoxication from the bowel by the normal or ordinary putrefactive products of food-digestion cannot be regarded as proven. Yet on this unstable foundation the most airy and far-reaching hypotheses have been reared. Herter attempted to place the matter on a sounder basis in his description of three types of chronic intestinal putrefaction:

1. *Indolic*, due to the *Bacillus coli*, and perhaps the *B. putrificus*. The commonest form is in marasmic, large-bellied children with chronic intestinal indigestion. Carbohydrates are not digested well, while proteins and fats are well borne. The subjects are sharp-witted; they are intolerant of cold, and are easily fatigued. Indican and other ethereal sulphates are markedly increased in the urine. For treatment he advises that the carbohydrates should be restricted to well-cooked rice or biscuits. Milk should be peptonized for a time, and a moderate amount of finely-divided meat given. Gelatin may be useful, because it contains no tryptophan, the precursor of indol. A few rather generous meals are better than frequent feeding. High irrigation of the bowel may be beneficial.

I think we are all familiar with a vaguer condition of this type in adults also. They are the subjects of headaches; the tongue is furred; the breath is heavy or offensive; the stools are light in colour. They are liable to ' bilious attacks.' There is a marked indicanuria. Such persons may easily go on to suffer from the further *Bacillus coli* infections discussed in the next section.

2. *Butyric*, chiefly due to *B. aerogenes capsulatus*. The nascent hydrogen causes much reduction of the bile pigment, so that there is excess of urobilin. Addition of a strong solution of mercuric chloride to the fæces produces a red colour, which is more distinct on throwing the fæces into water. There is little or no indican in the urine. Indefinite invalidism may be the chief symptom. The subject is often sour-smelling; the epithelium of the tongue and mouth is seen to be desquamating. Hence the irritable condition of the alimentary canal, with the tendency to diarrhœa. Shreds of epithelium may be seen in the fæces. In advanced cases an extract of the fæces may be hæmolytic in action. At this stage anæmia comes on —first a diminution in the blood volume, then of the hæmoglobin, and then of the red corpuscles.

Though the symptoms in adults are usually latent or chronic, in infants the *B. aerogenes capsulatus* may be virulently pathogenic. I recall a child of three that died with symptoms of acute bronchitis. Some petechial hæmorrhages into the stomach roused my suspicions, and the heart's blood, lung, liver, and spleen were found by Dr. Gordon to yield the *Bacillus aerogenes capsulatus*, which, on injection into guinea-pigs, proved to be very virulent, causing death in twelve hours, with hæmorrhagic necrosis of the subcutaneous tissues.

3. *Combined Indolic and Butyric.*—Nervous symptoms occur relatively early. The subjects become invalided more rapidly than with either indolic putre

faction or butyric fermentation separately. The outstanding features of the case are mental depression and muscular fatigue.

Specific Intestinal Intoxications.

These may apparently arise in one of three ways—

1. There may be alterations in the intestinal flora, so that bacteria can thrive which produce specific toxic substances.

2. The bacterial processes may spread up from the large to the small intestine.

3. Normal intestinal bacteria may pass into the blood in consequence of lowered resistance of the epithelium or lowered bactericidal power of the blood.

The *Bacillus coli communis* may be regarded as a normal inhabitant of the alimentary tract, but when it strays beyond its proper domain it may cause cholecystitis, gall-stones, cystitis, pyelonephritis, or phlebitis. Thus, according to Sidney Martin, the phlebitis of influenza is really due to a secondary infection by this organism. Such *B. coli* have a heightened virulence for animals. In this connection the premature appearance of the *Bacillus coli* in the intestines of bottle-fed children is important, because in early life the normal mucous membrane is more easily permeable by bacteria, while the intestinal flora should be less varied and less toxic. There is a parallel development of more putrefactive organisms and a higher resisting power. Therefore the *B. coli,* if

prematurely introduced into the infant's intestine, may prove virulently toxic. In a post-mortem examination I made of a premature child two days old, the only macroscopic lesions were hæmorrhages into the right lung, but the heart's blood was swarming with *B. coli*.

Another example of the way in which normal inhabitants of the bowel may intrude into damaged tissues with pathogenic results is seen in the engrafting of the *Streptococcus salivarius* or the *S. fæcalis* on to heart-valves already crippled by rheumatism, producing infective endocarditis.

In many instances it will be difficult, if not impossible, to draw a hard-and-fast line between intoxications and infections, because we cannot tell whether the microbe has been able to enter the portal blood-stream, and has become bacteriolyzed there, or whether the intestine has merely absorbed the toxins produced in the intestine. Indeed, we can sometimes recognize three stages in the same case—

1. Intestinal absorption of toxins only.

2. The organism in the portal blood, soluble toxins in the general circulation:

3. The organism in the general circulation—*i.e.*, septicæmia.

As an example of a disease that may be either an intoxication or an infection, we may take 'Louping-ill,' or paralytic chorea in sheep, because Hamilton's work on the subject is the model on which research will have to be carried out in man to establish the pathology of like conditions. Louping-ill is a terribly fatal disease

affecting sheep on the west coast of Scotland between the months of April and June. There are three stages—

1. The animal is apathetic, and staggers.

2. Spasmodic convulsions occur, which may go on to coma or to—

3. Flaccidity, with abolition of reflexes.

Sometimes there is diarrhœa with passage of blood. Recovery seldom, if ever, occurs. There may be excess of turbid and sometimes blood-stained peritoneal fluid, which contains a large, coarse-looking rod organism, with a great tendency to spore; and even clear peritoneal fluid showed the same organism on incubation in sealed tubes for twenty-four hours.

Injection of liquids containing spores reproduces the disease, and the same organism can be obtained from the walls or contents of the bowel. When the organism is injected subcutaneously, death takes place from acute toxic poisoning before the characteristic nervous symptoms can develop; when introduced by the alimentary canal, these are well developed. Hamilton bacteriolyzed the organism by the blood of sheep *in vitro*, filtered, and injected the filtrate subcutaneously, causing the characteristic symptoms. Thus an intoxication may occur, even though an infection has been prevented by the destruction of the microbe.

The cause of the periodicity of the disease appears to be that the blood is bacteriolytic to the organism at other seasons.

Immunity may be conferred by feeding an animal

on cultures during the period of the year that it is insusceptible, which recalls the immunity acquired to typhoid fever by the inhabitants of a district in which it is endemic.

I should like to emphasize the fundamental importance of these experiments, in which the method of infection is clearly worked out, and the line of successful treatment clearly laid down.

Horder has recorded an interesting example of the way in which the method of infection can be worked out in human beings. A boy, aged seven, had been playing in a field where the contents of a house privy were deposited. The next day he vomited and complained of abdominal pain. The temperature was intermittent, the stools contained mucus and blood, and he became jaundiced. On the twenty-sixth day the elder brother, aged twelve, was seized by an illness which began to run the same course. Cultures from the blood and urine were sterile. Cultures from the fæces were plated out, and agglutination tests were undertaken with the blood of both boys against the dominant strain of colon bacillus present in the fæces; clumping occurred readily. The conclusion was that the most probable cause of the portal infection was a virulent colon bacillus. As far as the general circulation was concerned, only a stage of intoxication had been reached, since the blood was sterile. A vaccine was prepared from this bacillus, and two doses given to each boy, with an interval of five days between the doses. Rapid improvement followed; and as the

cases were at different stages of their illness, the recovery could not be explained as the natural termination of the attack.

As I have deprecated indiscriminate reference to pyorrhœa to explain diseases of obscure causation, I should like to add that I have seen many cases of fever without physical signs traced to pyorrhœa, which have recovered on removing the offending teeth, perhaps with the aid of a vaccine prepared from them.

X-ray examination of the tooth sockets has proved a great help in recognition of this deep-seated septic absorption.

Microbic Cyanosis.—In 1902 Stokvis described cyanosis as a result of intestinal troubles. The abnormal colour was due to the presence of methæmoglobin in the red corpuscles. The patient had great intestinal irritation, clubbing of the fingers, deep cyanosis, and considerable albuminuria. After death it was discovered that he had suffered from parenchymatous nephritis, with ulcerative enteritis.

Van der Bergh found the connecting-link between the intestinal trouble and the resulting blood changes to lie in the presence of nitrites, which lead to the formation of methæmoglobin. He found that the condition would clear up in from twenty-four to forty-eight hours on a milk diet, but returned in four hours after an ordinary meal. He also described four cases of sulphæmoglobinæmia—*i.e.*, a sulphur compound of hæmoglobin, which in itself suggests an intestinal source for the intoxication.

Gibson described a case in a married lady, aged thirty-six, who had been cyanosed for two or three years. The face and hands were of a lavender hue, while the lips, ears, and nails were nearly as dark as bilberries. The spectroscope showed the band of methæmoglobin, while nitrites could be detected in the blood, fæces, and saliva. A coliform organism was isolated from the blood on one occasion only. Great improvement followed intestinal antisepsis, and methæmoglobin could no longer be found.

I had the opportunity of seeing the first case of sulphæmoglobinæmia recognized in this country, which was under the care of Dr. Samuel West at St. Bartholomew's Hospital.

An unmarried woman, aged thirty-seven, was admitted for debility and cyanosis. The skin was of a leaden hue, resembling that of silver staining. The colour was due to the blood, and not to deposited pigment, for on pressure the skin could be shown, when emptied of blood, to be of the normal hue. The fingers were not clubbed. I examined the blood spectroscopically in the circulation by holding the patient's hand in front of an electric light and pressing the web of the thumb between two glass slides until a convenient thickness was obtained. A spectrum closely similar to that of methæmoglobin was obtained, with a well-marked band in the red. I was at that time ignorant of Van der Bergh's work, and everyone regarded the case as one of methæmoglobinæmia. Drug habits were therefore suspected. These, how-

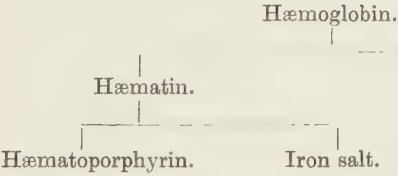
ever, could be excluded with an unusual degree of assurance. Her medical man stated that, except for occasional doses of bromide and iodide, he had given nothing more for a long time than a tonic of iron with arsenic. The patient lived in a remote part of the country, from which the nearest druggist's shop was some miles away; she could only have got drugs by post. But neither her family or the postman knew anything of her receiving such parcels. Moreover, during her stay in the hospital she certainly had no such drugs, yet the cyanosis persisted.

A more thorough examination of the blood by Wood Clarke revealed the fact that the bands were those of sulphæmoglobin. The urine contained less indol than usual—an interesting comment on the slight value to be attached to this body as evidence of an intestinal intoxication. The ethereal sulphates were greatly reduced. Nitrites were found in the urine. No increase in sulphuretted-hydrogen-forming organisms could be found in the intestine. A culture taken from the blood in the arm was sterile. Moreover, the long duration of the case was against the theory of an infection, and pointed rather to an intoxication.

Subsequently Mackenzie Wallis found in the mouth of this and four other patients with sulphæmoglobinæmia a nitrifying bacillus, which formed a strongly reducing substance. This substance, which was also present in the serum of all the patients, could reduce oxyhæmoglobin, an essential step in the formation of sulphæmoglobin. One case was apparently cured by

removal of the teeth and the use of an autogenous vaccine prepared from this nitrifying bacillus. The name 'microbic cyanosis' is therefore strictly applicable to the condition. These observations support the view I have already expressed that definite intestinal intoxications are due to abnormal pathogenic bacteria rather than to the ordinary products of putrefaction.

Hæmatoporphyrinuria.—This is the condition in which the hæmoglobin molecule is broken down into its constituent groups, so that one of its end-products, hæmatoporphyrin, appears in the urine. The decomposition of the hæmoglobin molecule may be tabulated as follows:



A trace of hæmatoporphyrin is a normal constituent of urine, but under certain conditions this is largely increased in amount, such as in sulphonal, trional, and tetronal poisoning. But there is another group of cases where such drugs can be excluded. When not occurring in the train of toxic symptoms, it has no specially unfavourable significance, though it denotes a disturbance of pigment metabolism.

Occasionally, however, toxic symptoms, such as vomiting, thirst, anorexia, abdominal pain, and profound prostration, occur with the hæmatoporphyrin-

uria. Ranking and Pardington described two such cases, and I had one under my care in which three attacks of this character had led to the suspicion of intestinal obstruction. McCall Anderson met with the combination of hydroa æstivalis with hæmatoporphyrinuria in two brothers. Monro has seen hæmatoporphyrinuria in periodic vomiting with acetonuria in a boy.

All these points are suspicious of an intestinal intoxication, and the suspicion is strengthened when we remember that hæmoglobin will break down into hæmatoporphyrin much more readily in the reduced state than when containing oxygen. Now Hurtley and Wood Clarke have shown that in the formation of sulphæmoglobin the blood pigment is first reduced, and then combines with the sulphur.

This suggests that in both cases some reducing agent is at work, and the intestinal symptoms point to the alimentary canal as its source. It is interesting to compare this condition with methæmoglobinæmia, which may also be caused either by intestinal intoxication or by coal-tar drugs.

In the future many other conditions may be proved to be due to intestinal intoxication, but the evidence is not at present convincing.

Hunter has laid great stress on oral, gastric, and intestinal sepsis as the cause of *pernicious anæmia*. There is a strong case for hæmolysis in the portal area in this disease. Now, the anærobic bacteria naturally present in the human intestine include some highly

pathogenic members which under proper surroundings can produce marked hæmolysis. Ultimately we shall probably find that many of the obscure intestinal intoxications are due to anærobic bacteria.

Though *cirrhosis of the liver* occurs in alcoholic subjects, direct administration of alcohol experimentally leads to a fatty and not to a fibrotic change in that organ. Consequently the condition has been referred to impurities in the common alcoholic drink of the country. Thus in wine-drinking countries the potassium sulphate with which the *vin ordinaire* is plastered, and in whisky-drinking countries the fusel-oil, have been held responsible. Such wide differences of opinion make it all the more probable that the ingredient common to them all, the alcohol, is really the agent at work. Rolleston explains this dilemma by the view that alcoholic excess leads to a prolonged gastric catarrh, which, by lowering resistance, enables toxic substances to be absorbed from the bowel. Hamilton's suggestion, which harmonizes with this quite well, is that a microbe is absorbed from the intestine, bacteriolyzed in the portal blood, and its liberated toxins anchored on to the liver substance. This might occur in other than alcoholic subjects, and it certainly appears that we cannot explain all cases of multilobular cirrhosis by alcoholism.

There is a growing opinion that many *chronic affections of the joints* are due to a chronic infection or intoxication. Either the alimentary or the genito-urinary tract may be the 'open door' by which the infective

agent enters. And so it has come about that pyorrhœa alveolaris has been regarded as a potent cause of rheumatoid arthritis.

At the Cambridge Research Hospital a history of infection was obtained in 20 per cent. of the cases, the most common being influenza. Defective teeth were found in more than 50 per cent.; but not much stress was laid on this, as a large proportion of the cases belonged to the lower classes, in which sound teeth are the exception. Indeed, on the methods of collecting statistics only too commonly adopted, I would guarantee to prove that any disease whatever was due to defective teeth. Still, there is sufficient evidence to make it desirable to pay careful attention to the condition of the mouth in rheumatoid arthritis. *Tetany* is another condition which has been held to be due to a gastro-intestinal intoxication. Its occurrence in rickets, with gastro-intestinal disturbances, in typhoid fever, and after lavage for dilated stomach is certainly suggestive.

But I do not wish to multiply the list of diseases for which an intestinal intoxication might be held responsible. For the present this is mere speculation. We may lay down the following conclusions as to etiology:

1. There is no satisfactory proof of intoxication by the ordinary disintegration products of digestion.

2. Putrefactive processes mainly affect the aromatic —*i.e.*, benzene—groups of the protein molecule; there is no conclusive evidence that these can lead to symptoms of intoxication. Occasionally the sulphur in the protein molecule appears to be able to cause chemical

changes in the hæmoglobin, with resulting cyanosis. But here, too, an abnormal bacterial agent is apparently at work.

3. It is often difficult, if not impossible, to draw a hard-and-fast line between an infection and an intoxication. The microbe may sometimes be able to establish itself in the blood-stream, thereby producing an infection, while sometimes it is rapidly destroyed by the blood, but it is, nevertheless, able to disseminate its soluble toxins in sufficient quantity to produce symptoms.

4. I believe we shall ultimately be able to refer all the real intestinal intoxications to the presence of actively pathogenic bacteria among the ordinary saprophytes of the intestine.

Treatment.

The indications are as follows:

1. *Avoidance of Putrefactive Contamination of Food.*—All food should be cooked as far as practicable. Cheese, especially the riper varieties, should be avoided. All fruit should be peeled. Careful attention must be paid to the teeth, since anærobic bacteria lurk in the interstices, and these are a great factor in intestinal putrefaction.

2. *Promotion of Prompt Digestion and Absorption.*—Here again attention to the teeth is important, to allow of proper mastication. Hydrochloric acid should be given if it be deficient in the gastric juice. But in the cases of butyric fermentation diastatic ferments are

better than hydrochloric acid, which is not well borne. Pepper, mustard, excess of salt, vinegar, and lemon, are irritant to these patients. Demulcent drinks are indicated. The butyric type need careful preparation for a generous diet. Emotional irritability or mental depression, increase in the ethereal sulphates of the urine, of gas-producing bacilli in the stools, or of intestinal flatulence, are signs that the food should be reduced. Intestinal flatulence especially indicates reduction in the amount of carbohydrates. If there be atonic dilatation of the stomach, lavage should be employed. Rest after meals should be enjoined.

3. *Limitation of the Number of Bacteria.*—Microorganisms form one-third of the total solids of the stools, though the greater number of these are dead. Intestinal antisepsis is a counsel of perfection, and at present we are scarcely prepared to accept Metchnikoff's dictum that senile changes are the result of an intoxication from the large bowel, so that it is hardly likely that we shall attempt intestinal antisepsis as a routine measure. Occasions have doubtless arisen in the experience of all when it has appeared desirable to make the attempt, though a sense of despair was felt in trying to accomplish it. Calomel in small and divided doses, followed by a saline purge next morning, is a time-honoured method of attempting to effect this. However useful this may be to start treatment, we must beware of a routine use of strong purgatives to this end, for, by removing the superficial epithelium of the bowel, they may facilitate septic absorption.

After a preliminary dose of calomel, my custom is to give 3 minims of cyllin medical in capsules three times a day for not more than four days. If continued longer than this, it is apt to cause irritative symptoms. After that naphthalene tetrachloride in 5 or 10 grain doses should be given three or four times a day. As it is insoluble and cannot, therefore, be absorbed, it does not produce any toxic symptoms. Salol has not been a success, and I have suggested the reason; but β-naphthol in 5-grain doses in cachets sometimes gives good results. A cachet containing 3 grains of benzo-naphthol with ¼ grain of menthol is useful where there is much flatulence. Izal, in doses of 3 minims, has been successful in some cases of paratyphoid infections. Thymol, manganese dioxide, hydrogen peroxide, and ichthyol, have all been recommended by various observers. Petroleum is not only aperient, but inhibits the growth of intestinal bacteria to some extent.

Treatment by Lactic Acid Ferments.—Metchnikoff has suggested another way of attacking this difficult problem. Instead of attempting to render the bowel aseptic, he advises the introduction of other organisms which are antagonistic to the growth of the putrefactive bacteria. These are the lactic-acid-producing organisms. Soured milk has long been a staple article of diet among Oriental people, and enjoys a high repute as a hygienic measure. James Riley, in 1854, claimed that it had an extraordinary effect in promoting longevity. He asserted that wandering Arabs, subsisting almost entirely on the fresh or soured milk of

camels, lived for two or three hundred years! It may be added that Riley was an American.

Bulgarian 'yahourth,' or 'yoghourt,' is milk soured by the most powerful lactic-acid-producing bacillus known. The commercial product contains a diplococcus and a strepto-bacillus also, but preparations of selected lactic ferments can be obtained.

The ridiculous way in which this lactic acid treatment has been boomed as a panacea has naturally excited a prejudice against it. In the first place, it is certain that in many instances no living Bulgarian bacilli have been taken at all; in the second, it has been used in totally unsuitable cases. Tablets of all kinds should be abandoned as a means of administering these organisms, which are too delicate to be able to survive such handling with any degree of certainty. Only fluid cultures or the milk actually soured by the bacilli should be employed. As to the selection of cases, the treatment can only be expected to be beneficial where there is definite evidence of increased putrefaction of proteins. Morbid conditions of the intestine may also be due to abnormal fermentation of the carbohydrates; in such cases the lactic acid treatment will only do harm. The reaction of the fæces will be a guide: if they are acid, this treatment is unsuitable; if they are alkaline at first, but yield a fair quantity of gas in the fermentation tube, showing an acid reaction after, the treatment will probably be unsuccessful. Good results can only be expected in the cases where the fresh fæces are alkaline, and remain

alkaline after twenty-four hours, yielding hardly any gas to the fermentation tube.

4. Guelpa's method of distoxication by a combination of fasting, purgation, and diuresis has had excellent results claimed for it by various observers. The method is as follows: For three or four days, and sometimes longer, a bottle of purgative water is taken. Guelpa recommends that the following mixture should be dissolved in half a litre of boiling water:

Magnesium citrate	dr. x.
Calcined magnesia	gr. xxx.
Sodium chloride	gr. xv.
Essence of citron	♏x.

Half of this to be taken in the morning quite hot, and the rest to be taken ten minutes later. During these days no food of any sort is taken, but a mineral water, such as Evian, is drunk freely, or a tisane, such as Tilleul, sweetened with a little saccharin. As after all fasting procedures, ordinary diet should only be cautiously resumed. I have not used the method.

5. *Plombières' Douches* may be tried. It is important that they should not be given more frequently than three times a week, and that not more than 18 inches of pressure should be used. The treatment should not be continued more than about three weeks. If these precautions are not observed, mucous colitis is almost certain to be produced.

6. *Mechanical Supports.*—When there is definite visceroptosis, much help may be derived from a well-fitting abdominal support. In my opinion, Curtis' is the best.

7. *Surgical Procedures*, such as irrigation of the colon through an appendicostomy wound, short-circuiting, and even excision of the colon, have all been advised. They can seldom be required, and should only be considered when all medical means have failed.

8. *Vaccine Treatment of Intestinal Intoxications.*— The most rational procedure is to try and isolate the microbe responsible, if possible, but the results have been rather disappointing. If a blood culture be sterile, a plate culture may be made from the stools, and the effect of the patient's blood in agglutinating or destroying the more definitely pathogenic organisms tried. If we get a positive reaction with one or more of these, a vaccine should be prepared from such organisms. If it benefits the patient, we shall at once have established the fact that the case is really one of an intoxication, and have initiated the rational treatment for it. In the case of *Bacillus coli* vaccines, Sidney Martin advises beginning cautiously with small doses, such as one to four million.

At present it is not practicable to work out cases in ordinary practice in this way, but we may look forward to a time when we shall be able to correlate certain definite signs and symptoms with certain distinctive microbes. The lines along which advance may be made will be evident. Casually testing the urine is not sufficient for diagnosis, nor does purgation and extraction of the teeth comprehend the methods of treatment.

CHAPTER XI

IRREGULAR ACTION OF THE HEART

During the last few years much attention has been given to the study of cardiac irregularities in consequence of the introduction of Mackenzie's polygraph and Einthoven's string galvanometer, which have rendered the recognition of the various types possible. This is a gain, for the interest taken in cardiac murmurs had rather distracted attention from the cardiac rhythm. But our aim in treatment is to restore a normal rhythm; we cannot repair a valve. After all, the only value of a murmur is that it enables us to form an opinion as to the condition of the valves, and deduce the probable effect upon the heart muscle.

It would be unfortunate, though not surprising, if this activity in research created the impression that the subject had become too complex for any but specialists to appreciate. Although it requires special training to obtain or to interpret a curve obtained with the polygraph or galvanometer, certain simple main conclusions have been reached which affect everyday practice. I propose to describe the chief types of irregularity, to explain their production and significance,

and to show how far their recognition is now possible by means of the associated signs and symptoms, without the aid of elaborate apparatus.

It is to Gaskell that we owe our fundamental conceptions of cardiac rhythm. Here, as in his pioneer work on the sympathetic nervous system, his philosophical insight enabled him to lay the foundations so well and truly that it has only been left to others to build along his lines. After more than twenty years this work was applied to clinical medicine, with excellent results.

Previous to Gaskell, physiologists had referred the rhythm of the heart to the intracardiac ganglia. Bernstein had shown that if the ventricle of the frog's heart were ' physiologically disconnected ' by crushing the auriculo-ventricular junction with a fine pair of wire forceps, it remained quiescent, while the rest, which contained ganglion cells, continued to beat. But Gaskell showed that if the intracardiac pressure were raised by ligaturing the aortæ, the ventricle would beat rhythmically once more.

In the tortoise's heart he was able to divide the septal nerve which passes between the two intracardiac ganglia without disturbing the rhythm; and by a series of interdigitating cuts in the auricular substance he compelled the wave of contraction to pass along a zigzag strip of muscle between the sinus venosus and ventricle, though all nerves must have been divided. Finally, by warming the ventricle and cooling the sinus, he was able to alter the relative excitability of the two

ends of the heart so much that a reversed rhythm was produced. His conclusion was that rhythm was an inherent property of the cardiac muscle, and did not depend on the intracardiac ganglia. The beat normally began at the sinus, because here the muscle was of a more embryonic character, while the ventricular muscle was the most differentiated.

He also showed a point which has now become of great practical importance. If the bridge of auricular muscle be made too narrow by cutting, a ' block ' is established on the course of the muscle wave, so that not every beat can pass over into the ventricle, but only alternate waves, or one out of every three, according to the width of the bridge. But after inhibiting the heart by stimulation of the vagus, the muscle accumulates enough energy during the enforced rest to enable it to convey every beat across the narrow bridge. On the other hand, in the period of comparative exhaustion following sympathetic stimulation, the conductivity is lowered, so that fewer beats can pass over. An adequate strand of conducting tissue is essential to the due propagation of the wave of contraction along the cardiac tube.

Stanley Kent, in 1893, was the first to apply these results to the mammalian heart by proving the existence of muscular continuity between auricle and ventricle. His, and then Tawara, worked out the nature of the connecting band or ' auriculo-ventricular bundle,' as it is now called, in much greater detail. It begins near the anterior edge of the right coronary

vein, and then passes forward on the right side of the auricular septum below the foramen ovale. Just below the insertion of the median flap of the tricuspid valve this bundle forms a knot-like thickening, the auriculo-ventricular node or *Knoten*. From this knot a process arises which penetrates the fibrous septum, and runs along just below the pars membranacea of the septum, dividing into two main branches, which pass obliquely downwards, one on either side of the septum under the endocardium. So far these fibres do not blend with those of the ordinary cardiac muscle, being enclosed in a separate fibrous sheath; but when they reach the papillary muscles they divide into a large number of branches, some of which enter the papillary muscles, while others pass on beyond them and follow the course of the small trabeculæ to the parietal wall, where they branch upwards and downwards under the endocardium lining the whole inner surface of the cavity of the ventricle, to fuse everywhere with the ordinary cardiac muscle fibres.

The heart muscle of elderly people being of a brownish colour, the left main branch, with its two secondary branches, stands out very plainly on account of its rather greyish-white colour, but it can be recognized with practice even in the hearts of younger individuals. The hode is made up of fine, pale, thin, branching fibres with faint striation, which in some respects resemble embryonic muscle fibres. The fibres interlace and fuse with one another, thus contrasting with the elongated parallel arrangement of the rest of the

cardiac muscle. The branches and terminal filaments of the bundle resemble the fibres, described in 1845 by Purkinje, in the subendocardial layers of the sheep's ventricle. Morphologically and histologically these fibres represent the invaginated portion of the primitive tube from which the complex heart of the mammal is built up.

But if these primitive fibres are the conducting strand along which the wave of cardiac contraction passes, we should expect to find them at the junction of the great veins with the heart, for this is where the wave starts. Keith and Flack found a remnant of primitive fibres persisting at the sino-auricular junction, in close connection with the vagus and sympathetic nerves, and having a special arterial supply. This is called the 'sino-auricular node.' Here the dominating rhythm of the heart normally arises, and here it may readily be modified by those extrinsic nerves which are known to influence it.

Between the sino-auricular node and the auriculo-ventricular bundle there appears to be no strand of specialized tissue, though one observer, Thorel, claims to have found one. As we pass from the lower to the higher vertebrates, the primitive tissue becomes reduced in amount, and more concentrated in position; a single strand of communicating muscle fibre is peculiar to the mammalian heart. With this reduction the heart becomes less automatic in its action, and more in subjection to the central nervous system. Indeed, the nodes are extremely intimate neuro-mus-

cular contacts. They have even been compared to the muscle-spindles of voluntary muscles—*i.e.*, sensory rather than motor structures. Without going as far as this, we may admit that the bundle is not only a conducting, but a co-ordinating mechanism. Keith found in a case of heart-block of eighteen years' standing that the bundle below the site of destruction was quite healthy. If it were merely a conducting bundle, it must have atrophied. As it did not, it must have some other function: it can create and co-ordinate as well as conduct a stimulus.

The anatomical and experimental evidence is in favour of extending Gaskell's conceptions, slightly modified, to the mammalian heart. Hering was able to produce a complete stoppage of the supraventricular parts of the heart by a cut made at the sino-auricular junction; while Erlanger has shown experimentally that it is possible, by interfering with the auriculo-ventricular bundle, to reproduce the phenomena described by Gaskell in the tortoise's heart, and many of the forms of irregularity met with clinically. A clamp was devised in which a small piece of tissue, including the bundle, could be subjected to varying degrees of compression while preserving its normal relations. With very slight compression there was merely a lengthening of the normal pause between the auricular and ventricular contractions. These intersystolic periods, however, usually lengthen until eventually the ventricles fail to respond to one of the excitation waves. In the next cycle the intersystolic

period, owing to the increased excitability of the rested ventricular muscle, is unusually brief. In succeeding cycles it again progressively lengthens until the ventricles again fail to contract.

On tightening still more, further stages of heart-block occur, the auricles giving three or four beats to each ventricular contraction. When efficient waves get through from the auricles at longer intervals, the ventricles begin to beat independently. Thus a complete dissociation of the auricular and ventricular rhythm results.

Before discussing the clinical equivalents of these phenomena, it will be well to consider a little more closely the physiological peculiarities of cardiac muscle. The following facts throw some light on its rhythmical power:

1. If a resting cardiac muscle be stimulated by a series of shocks, a progressive improvement is seen in the first few beats, producing the so-called *staircase*. Each beat acts as a stimulus to the next, so that a rhythm, once started, tends to be maintained. This is apparently due to the stimulating effect of the carbon dioxide produced by the muscle. Carbon dioxide is thus a stimulant both to the heart and the respiratory centre, providing in this way for its own removal.

2. *All shocks are maximal* to the cardiac muscle—that is to say, whether a large or small shock be given, the response is the same, the muscle giving the best beat it is capable of at that moment. This is not a

contradiction of the previous statement; the staircase would be seen just the same whether large or small shocks, or shocks of varying strength, were used. As long as the stimulus is effective the muscle gives the same response to each.

3. Cardiac muscle has a *long refractory period*. If a shock be sent in just after a beat has begun, the stimulus is ignored; if it be sent in a little later, a small beat is given after the ordinary one; but the heart makes up for this by a longer pause, so that the third beat does not start till the usual time. It is therefore impossible to throw heart muscle into tetanus.

These facts can be partly explained on the analogy of a gun. When the gun is loaded, it does not matter whether much or little force is expended in the pulling of the trigger, the whole charge is fired off; and when the charge has been fired off, it does not matter how forcibly the trigger is pulled, there is no response. The analogy fails in that we are able to get a small contraction when the fibre has partly recharged itself. All this points to an elaboration of contractile material in the muscle substance, which is 'fired off' as soon as enough is accumulated. Normally the charge is fired off by the train laid in the auriculo-ventricular bundle.

We do not know at present what the charge is composed of, but we do know that ionized salts play a large part in its elaboration. For whereas dialyzed serum will not maintain cardiac rhythm, a saline fluid, such as Ringer's, which contains salts of sodium, potassium,

and calcium, is highly efficient for this purpose. If potassium be omitted the heart does not relax properly, while if calcium be left out systole becomes imperfect. And Locke has shown that the addition of dextrose and oxygen to Ringer's fluid makes it a remarkably efficient medium for maintaining rhythmical contractions in an excised heart. In the presence of these substances, then, the heart is able to keep up a supply of its contractile material.

This is not really incompatible with Carlson's ideas. According to him, the peculiarities of cardiac contractions are due to the heart wall being an intimate blend of muscle and nerve. His conclusions were reached by studying the contractions of the heart of *Limulus*, or king-crab. Here the muscular and nervous elements are anatomically separable, and the muscle is found to approximate in its reactions to those of ordinary muscle. And Rohde found that on perfusing chloral hydrate through the mammalian heart, a stage was reached at which the heart responded to direct stimulation like ordinary muscle. It was then readily tetanized, the characteristic refractory period was not in evidence, and the heart responded to stimuli of gradually increasing strength with contractions of gradually increasing amplitude. His interpretation was that chloral had accomplished pharmacologically the severance of the nervous and muscular elements, which can be performed anatomically in *Limulus*. If we regard the cardiac wall as neuro-muscular in structure, it does not dispose of the argument that the rhythm is

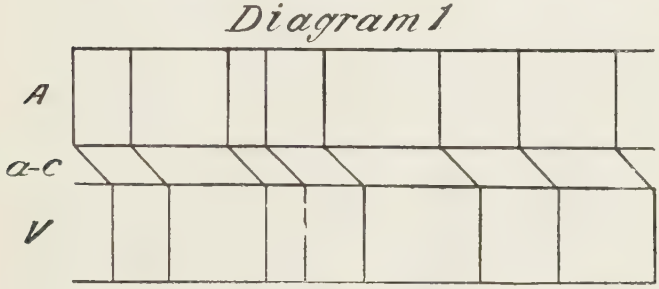
independent of the macroscopic ganglia, but is conducted along a strand of embryonic fibres which represent the remains of the primitive cardiac tube.

Types of Disturbed Cardiac Rhythm.

We can classify the principal types of cardiac irregularity in terms of disturbed function of this primitive cardiac tube. If the rhythm be initiated irregularly at the sinus venosus, we have the type known as *sinus irregularity;* if the contraction of the auricle between the sino-auricular node and the auriculo-ventricular bundle is disorderly, we have auricular fibrillation. An abnormal stimulation of the tube at some point below the sinus results in a smaller premature contraction or *extra-systole;* a diminution in the conducting power of the bundle prevents each contraction of the auricles from being followed by one of the ventricles, *heart-block.* Finally, owing to exhaustion of contractility the beats may vary in strength, *pulsus alternans.* Most forms of irregularity can be explained as due to one or more of these conditions.

1. **Sinus Irregularity.**—The remains of the sinus venosus at the entrance of the great veins is the normal ' pacemaker ' of the heart and sets the rhythm. In sinus irregularity the rhythm is initiated at the normal place, but not at the normal time. Once the wave of contraction is started it is propagated quite normally. The duration of systole remains constant, but the diastolic intervals vary. As the pulse quickens

it is the diastolic intervals that are encroached on, so that this type of irregularity tends to disappear as the heart quickens—as, for instance, in fever. On the other hand, it is apt to appear for the first time, or to reappear as the heart slows down after a febrile attack. Windle has noticed that it is common in children in such circumstances. The dog is very liable to this



SINUS IRREGULARITY.

A represents the auricular beat as determined by the jugular pulse. *V* represents the ventricular beat as determined by the carotid pulse. *a-c* represents the interval taken up in the passage of the impulse along the auriculo-ventricular bundle from auricle to ventricle. In sinus irregularity the inception of the rhythm occurs at irregular intervals, but each beat, when started, is carried out in a regular manner.

form of irregularity, which disappears after section of the vagus. It is therefore probably due to vagal irritation—a view supported by the fact that when the vagus is unduly irritable, sinus irregularity can be induced reflexly by swallowing or by hurried respirations—two acts in which the sensory branches of the vagus are stimulated.

Sinus irregularity can be recognized by the fact that though the pulse-rate is varying, usually with respiration, the beats are equal in strength, while on auscultation the interval between the first and second sounds is constant. It is met with in healthy people as well as in neurasthenics. It does not cause any real inconvenience, and is generally detected merely by examination. Its recognition is important simply that undue significance may not be attached to it. In short, an irregularity that disappears with a rise of temperature need not trouble us. It is true that it may occur in cerebral diseases, such as tuberculous meningitis, but its presence does not affect the gravity of the condition in any way.

2. **Auricular Fibrillation.**—*Interference with the passage of the wave from sinus to ventricle owing to irregular and inadequate contractions in the auricle.*

This is the irregularity seen in the later stages of mitral disease, especially mitral stenosis. James Mackenzie has called attention to the way in which the typical crescendo presystolic murmur may suddenly vanish. A diastolic murmur, diminuendo in character, may be present, but its method of production is different. The crescendo murmur is due to auricular contraction, while the diastolic murmur is due to the blood which has been stored up in the auricle during ventricular systole flowing through a constricted orifice as soon as the ventricle passes into diastole. The former is an active change, the latter is passive. At the same time the jugular pulse changes in character,

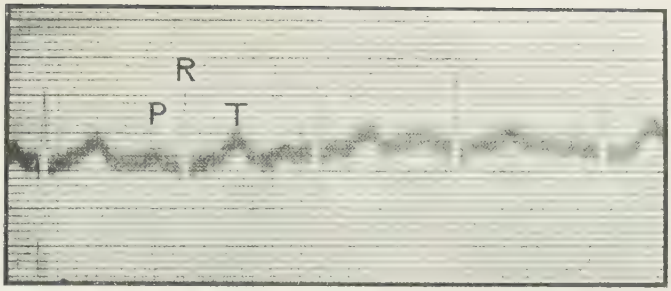


FIG. 1.—ELECTROCARDIOGRAM OF NORMAL HEART.

The abscissæ are divided at intervals of $\frac{1}{25}$ sec. *P* represents the auricular and *R* the beginning of ventricular contraction. *T* is taken to represent the end of ventricular systole.

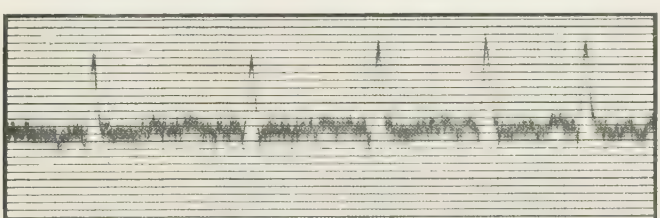


FIG. 2.—ELECTROCARDIOGRAM OF AURICULAR FIBRILLATION.

Note that the auricular wave *P* of Diagram 1 is replaced by a large number of small waves produced by the feeble irregular contractions of the fibrillating auricle, and that the intervals between ventricular waves are unequal.

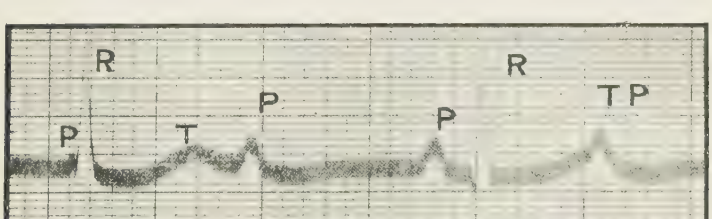


FIG. 3.—ELECTROCARDIOGRAM OF COMPLETE HEART-BLOCK.

Note that the first *P* wave almost coincides with *R*, while the second *P* wave is not followed by any ventricular wave. The fourth *P* wave has fused with the *T* wave. This shows complete dissociation of auricular and ventricular rhythm.

presenting no evidence of an auricular contraction in the normal period.

Lewis found, by Einthoven's string galvanometer, that the ordinary wave of auricular systole is replaced by a number of very fine waves with a frequency of 200 to 300 oscillations a minute. Probably the overstretched muscle of the auricle with its obstructed outflow has become incapable of orderly contraction. This is supported by Lewis's observation that a rise of venous pressure produced by squeezing the abdomen may produce a paroxysm of auricular fibrillation, and by the fact that when auricular fibrillation is experimentally produced in the dog the auricle is seen to be 'ballooned.' In the arterio-sclerotic cases there has been found degeneration of the coronary arteries. In either case the auricular muscle is rendered more irritable but less effective. The auricular stimulus reaches the auriculo-ventricular bundle in a rapid and highly irregular rhythm, to which the ventricles can respond only in an irregular manner.

Auricular fibrillation can generally be recognized even without special apparatus by the following points: (1) The pulse is completely irregular. There is no relation between the size and the strength of the beats and the preceding diastolic pauses, such as is found, for instance, with extra-systoles. (2) The veins in the neck are distended, causing a feeling of fulness, and the only large wave seen in them is synchronous with ventricular systole. (3) The disappearance of the typical presystolic murmur of mitral stenosis. (4) With

the onset of auricular fibrillation the subjective symptoms become increased. Anginal pain, a fluttering sensation, faintness, pallor, and dyspnœa with orthopnœa are common. If they occur suddenly with an irregular pulse, they are almost always due to fibrillation.

In consequence of the rapid disorderly rhythm imposed on them, the ventricles are placed at a great mechanical disadvantage, and it is to this that the serious symptoms are due. If the ventricular rhythm can be made slower and more regular, enough blood can be aspirated from the auricles into the ventricles for the purposes of the circulation, even though the former remain in their state of paralytic distension. The action of digitalis is more successful in the auricular fibrillation of mitral stenosis than in any other class of case, and a few doses may change the condition from one of acute distress to one of comparative comfort. This is apparently due to its depressing effect on conductivity, producing, in fact, a mild degree of heart-block, so that the auriculo-ventricular bundle ignores a large number of the irregular stimuli it receives from the fibrillating auricle. It may be necessary to give it in full doses of 15 to 20 minims if smaller doses do not produce the desired effect. In Mackenzie's opinion there is no risk in doing this, as the first toxic action of the drug is headache or nausea and vomiting, which would lead to its discontinuance. When it has exerted its steadying effect on the rhythm, it can be reduced to the smallest dose sufficient to maintain the

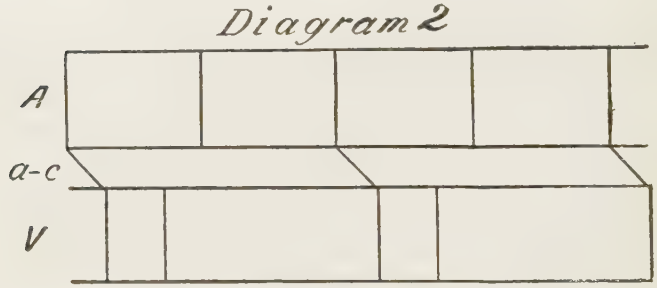
effect. The appearance of coupled beats is a sign to stop digitalis for the time. The influence of the drug is much less if there is fever, especially if the fever is due to something which infects the heart muscle. Of this a recurrence of rheumatism is a good example. Its action is less marked in the cardio-sclerotic cases, because there is generally more degeneration of the myocardium.

In mitral stenosis I have sometimes found the blood-pressure as low as 80 minims during the attack of fibrillation, and here digitalis has been very effective. It is often said that auricular fibrillation once established is permanent, even though the effect of digitalis may be sufficient to restore a normal rhythm in the ventricles. But certainly it is sometimes a paroxysmal condition of short duration. Whenever fibrillation occurs it plays an important part in the ultimate breakdown of the heart.

3. **Extra-Systoles.**—*Premature contractions of the auricle, or more usually of the ventricle, in response to a stimulus from some other portion of the heart than the sino-auricular node, but where otherwise the fundamental rhythm is maintained* (Mackenzie).

When a stimulus is initiated at some other part of the heart than the sino-auricular node a premature contraction will occur, and as the heart has not had time to accumulate enough contractile material, this beat will be smaller than normal, and, for a similar reason, it will be followed by a longer pause. This disturbance of rhythm constitutes the extra-systole, and usually involves the ventricle alone, though it may

occasionally implicate the auricle. It had been produced experimentally many years before its clinical counterpart was known. It can be detected by the premature pulse in the radial artery followed by an abnormally long pause. On auscultation the regular sequence of the heart sounds is occasionally interrupted by two sharp sounds, or only one may be heard if the



EXTRA-SYSTOLES.

Note that the auricular beats are regular, but that a premature ventricular beat occurs after the normal one. The next auricular beat, therefore, reaches the ventricle during the refractory period, and consequently is not followed by a ventricular contraction. The letters have the same significance as in the former diagram.

beat is feeble, followed by a long pause. On examining the venous pulse in the neck while auscultating it may be noted that a large auricular wave comes just *after* the premature beat of the ventricles. This is due to the fact that the auricular rhythm occurring at the normal time has to attempt to drive blood into a ventricle already in systole, and failing to do this, a larger volume of blood is driven back into the great veins.

The chief sensation of which the patient complains is the long pause after the extra-systole, ' as if the heart had stopped,' or a ' thud ' which accompanies the beat following the pause.

Too much importance must not be attached to this form of irregularity in the young, in whom it is not uncommon. Mackenzie says: ' I have followed cases for many years, and watched them pass through seasons of sickness and stress, and have seen no reason to attach any serious import to this symptom.' But in a syphilitic or in later life, if the blood-pressure is persistently raised, it may have a more serious significance, suggestive of impending heart-block. At first sight extra-systole seems diametrically opposed to heart-block, being due to increased irritability of the auriculo-ventricular bundle instead of diminished conductivity. But it has been found both experimentally and clinically that slight lesions of the bundle may cause extra-systoles by stimulating it, while severer lesions may obstruct the conduction of a wave through it. Mackenzie found that the long pause after an extra-systole is due to difficulty in the passage of the wave through the bundle, indicating that in its diseased condition a premature beat uses up so much of its energy that it is incapable of responding for some time. He found that the wave may take as long as a fifth of a minute to pass from auricle to ventricle as measured by the interval between the auricular wave in the jugular vein and the carotid impulse. This interval rarely exceeds a fifth of a second in a normal heart.

Paroxysmal tachycardia is due to the less common condition of extra-systoles starting in the auricles. Although this does not strictly constitute irregularity except when the paroxysms last but a few seconds, it will be convenient to consider it here with the conditions to which it is so closely allied. Lewis (*Lancet*, 1912, ii., p. 1418) describes the features of a simple tachycardia such as occurs in exophthalmic goitre, pulmonary tuberculosis, infective conditions, and alcoholism, as follows: The pulse-rate falls during rest or recumbency, rising to the original rate on standing up again; it is enhanced by exercise, emotion, and the like; the electro-cardiogram is of the normal type, and the rapidity is gradual in onset and termination. This simple tachycardia should never, in the absence of other signs, suggest a cardiac lesion.

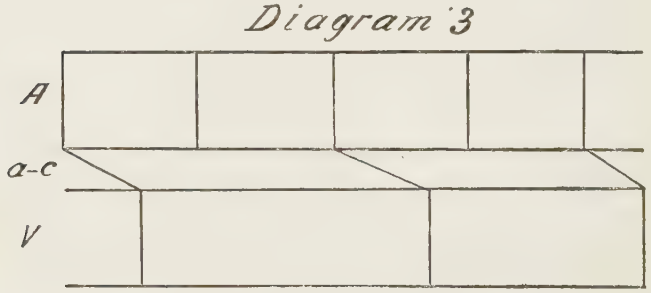
There are pathological types of tachycardia, on the other hand, which appear and disappear abruptly, and are uninfluenced by posture and exercise. In these the auricular portion of the electro-cardiogram shows a decided departure from the normal. This is due to an irritable focus in the auricle, and the auricular extra-systoles are initiated there, passing onwards to the ventricle as usual, but *backwards* to the entrance of the great veins, thus inverting the auricular wave in the electro-cardiogram. Such a tachycardia rarely, if ever, produces contractions more frequently than 200 times a minute. Lewis distinguishes, however, a condition of 'auricular flutter,' in which the auricular beat may rise as high as 335 a minute, but, as may be

imagined, the ventricle can rarely keep up such a pace. It may respond to every second or fourth auricular beat, or it may respond unevenly, producing obvious irregularity. His reason for separating 'auricular flutter' from simple paroxysmal tachycardia is that the former may pass, or be forced by the administration of digitalis, into auricular fibrillation. But probably no hard-and-fast line can be drawn, flutter representing the more extreme grade of auricular extra-systoles, and therefore being more likely to produce an exhaustion of the auricle. When the tachycardia lasts for weeks or months, it is probably due to flutter. This condition is more responsive to digitalis than the ordinary paroxysmal form, in which all remedies are uncertain. The spontaneous ending of paroxysmal tachycardia has led to various forms of treatment being credited without justification with producing the desired effect. Lewis thinks that the tachycardia described by Da Costa in soldiers belongs to several different categories, and that many cases were the sequel of the infective diseases prevalent in warfare. This accords with my experience in the South African War, where camp diarrhœa was the usual precursor of paroxysmal tachycardia.

4. **Heart-Block.**—*Every auricular contraction is not followed by a ventricular contraction.*

This condition has been known since the middle of the last century as Stokes-Adams disease, but its significance and the method of its production have been appreciated only during the last decade. Its features

are—(*a*) slow pulse, at first paroxysmal, but tending to become permanent. The commonest rate is 30 a minute, but 20 or even as low as 6 have been observed. (*b*) The auricular contractions, as evidenced by the wave in the jugular vein, remain approximately normal, however, and even by inspection it may be possible to make out that only one out of every two, three, or four contractions of the auricle are followed by a



HEART-BLOCK.

Note the lengthened *a-c* interval, also that each auricular beat is not followed by a ventricular contraction. The letters have the same significance as in the former diagrams.

ventricular contraction. (*c*) Attacks of vertigo, syncope, or epileptiform convulsions.

The condition was originally thought to be due to atheroma of the bulbar arteries, causing the fits and leading to inhibition of the heart through vagal stimulation. Although the vagus acts mainly on the auricles, which maintain their normal rhythm in heart-block, no doubt it plays some part by depressing conductivity.

A heart in which conductivity is already impaired would be unduly sensitive to ordinary vagal inhibition. But the anatomical changes found in Stokes-Adams disease point strongly to the conclusion that the cause is a lesion of the auriculo-ventricular bundle, the cerebral symptoms being due to anæmia of the brain resulting from the defective circulation.

The following are some of the principal changes that have been found: Gummata (Handford, Keith and Miller); anæmic necrosis consequent on thrombosis of the nutrient arteries (Jellick, Cooper, and Ophuls); fibrosis (Barr, who, however, does not admit the significance of this; Schmoll, G. A. Gibson, A. G. Gibson); new growth (Sendler, Luce); atheroma (Stengel, Aschoff); fatty infiltration (Aschoff). That similar symptoms can be produced by pathological conditions so diverse supports the idea that the one feature common to them all—*i.e.*, interference with the conducting bundle—is the essential cause.

Temporary heart-block has also been described in acute rheumatism and influenza. This is probably due to the bundle becoming involved in the inflammatory lesions of the myocardium, which are by no means uncommon in rheumatism and septic states. Recovery may be complete, or fibrosis may follow, producing organic changes in the bundle in later life.

Heart-block has been observed in asphyxial conditions, even after both vagi have been cut. Lewis and Mathison believe that the lactic acid resulting from oxygen starvation poisons the conducting tissues. It

has also been excited by digitalis, aconitine, physostigmin, adrenalin, squills, and strophanthus, but apparently in all these cases there was impaired conductivity before the drug was given.

The following case, under my care, exemplifies the clinical features of this disease:

A man, aged thirty-nine, was admitted into hospital for numbness of the extremities and headache. There was nothing of importance in his past or family history. The heart-sounds were rather faint, but there was no murmur. His pulse was 80 and regular. The systolic pressure was 120 millimetres. The urine was free from albumin. Three days later he complained of epigastric pain and tightness across the chest. He said that he could feel 'something jumping about inside.' The frequency of the radial pulse was now only 20, while the frequency of the venous pulse in the neck, which was very marked, was 80. A soft systolic murmur could now be heard at each contraction of the ventricles. On the X-ray screen thirty-two auricular contractions could be counted to nine ventricular. The dissociation of rhythm was clearly visible. Under strychnine and caffein the normal rhythm soon returned. Two days later the drugs were discontinued; within fourteen hours he had another attack. 'Everything in the room was turning round,' he said, and he was evidently in great distress. The pulse at the wrist fell to 16, while the venous pulse was 90. He was given strychnine subcutaneously, and caffein by the mouth. Again he rapidly improved.

Under treatment the attacks diminished in frequency, though in one the pulse fell to 12. After about three weeks' immunity he had a series of severe attacks, being unconscious during the periods of bradycardia, and regaining consciousness as the pulse revived. He then passed into an epileptiform state, in which he bit his tongue and lost control over the sphincters, while the legs and back were quite rigid. For about three days he passed through these phases in turn: the ventricles stopped and he became unconscious; the pulse returned, he became convulsed or excited. On several occasions competent observers believed him to be dead, yet on powerful stimulation the heart could be made to beat again, and he came back to life for a time. At last it stopped for ever.

The heart was found to be only slightly hypertrophied, and there was a little atheroma of the coronary arteries. No other signs of disease could be found until the muscular tissues near the auriculo-ventricular bundle were examined microscopically in serial sections, when degenerated fibres were found embedded in a mass of fibrous tissue.

There had evidently been a progressive fibrosis involving the bundle of His, so that a partial heart-block ultimately became complete. At first drugs which improved conductivity were able to combat this, but as the strand of connecting tissue became narrower they failed. Even in complete heart-block the ventricles may continue to beat slowly and independently, for they have a rhythmical power of their

own. This, however, is not adequate to maintain the circulation efficiently.

As a large proportion of cases of heart-block are due to syphilis, Wassermann's reaction should be tried in every case, and if it is positive, vigorous anti-syphilitic treatment must be carried out, for though often disappointing, it affords the best chance of relief. In young people with a history or symptoms of rheumatism effective doses of sodium salicylate should be given, for there is no commoner cause of heart-failure in the young than rheumatic carditis. Atropin is indicated on theoretical grounds, as it paralyzes the inhibitory action of the vagus, but it does not appear to give good results when the block is complete. Caffein and strychnine should be given during the paroxysm. They both appear to improve conductivity, and the former diminishes the action of the vagus on the heart as well. Theobromine may suit the cases with high blood-pressure better than caffein. Digitalis is contra-indicated as long as the block is incomplete, since it depresses the conductivity of the bundle. But, as Lea and others have pointed out, when the block has become complete digitalis cannot depress conductivity any further, while it may improve the contractions of the independently acting ventricle.

5. **Pulsus Alternans.**—*A regular succession of small and large beats.* Wenkebach explains it as follows: When contractility is depressed, a strong and full contraction will encroach upon the period of rest, so that when the next stimulus arrives contractility has not

sufficiently recovered, and a smaller and shorter contraction results. As this contraction is shorter, the period of rest is lengthened before the next stimulus arrives, so that the next contraction will be longer and stronger, and so on. Now, one of the chief causes of a full and strong contraction is increased resistance to the flow through the peripheral vessels, such as occurs in arterio-sclerosis. Mackenzie has found that high blood-pressure has an important influence in producing the pulsus alternans. In healthy hearts the period of rest is so long that a little increase or shortening has no perceptible effect upon the size of the beat, but in damaged hearts a very little variation in the period of rest has a manifest influence on the subsequent contraction. Whereas deficient conductivity will lead to heart-block, impaired contractility will lead to pulsus alternans. Sooner or later both functions are apt to become depressed, when extra-systoles will appear with the alternating pulse, producing a very confusing irregularity. Pulsus alternans may be brought out only on exertion, and it is well to try the effect of exercise in suspected cases. It is difficult to recognize the condition by the finger even when the pulse tracing shows obvious alternation. The difference in the force of the beats is more readily detected if the vessel is firmly compressed. This pulse implies a grave condition, for it is the expression of an exhausted heart, with great impairment of its reserve force. According to Davenport Windle, the practical value of recognizing this altered rhythm is that it occurs in aged

people before the symptoms of heart failure. Thus it is a danger signal. He states that in any patient with arterial disease and alternating pulse the occurrence of angina may be confidently predicted, unless dropsy sets in, when angina, if previously present, ceases as a rule.

Apart from angina, the dominant symptom is apparently causeless breathlessness. If this occurs in an elderly patient with high pressure, but in whom the heart is only a little enlarged and free from valvular defects, the lungs clear and the kidneys not evidently diseased, the presence of alternating pulse is probable. The dyspnœa is sometimes paroxysmal, or there may be Cheyne-Stokes respiration. The gravity of pulsus alternans may be gathered from the fact that in Windle's series of seventeen cases no patient lived longer than seventeen months after he first observed pulsus alternans. Its diagnosis from the bigeminal pulse of ventricular extra-systoles is important, for the latter means no more than increased excitability of the heart; and although it may be associated with cardio-sclerosis, it is in no sense an index of the degree of myocardial degeneration, and does not afford any indication as to the expectation of life. The distinguishing point is that in extra-systoles the long pause follows the small beat, while with an alternating pulse the intervals may be equal, or if unequal the shorter pause follows the smaller beat. On auscultation the characteristic rhythm of the extra-systole will be recognized. It may be expressed thus: 'Lub—dup tu tup,' followed by a long pause.

Conclusions.—Though much remains to be worked out, we have already learned much as to the widely different significance of the various types of irregularity. Sinus irregularity has no real significance. Extrasystoles, produced either in the auricle or ventricle, mean increased irritability of the heart, but not necessarily any serious organic defect, and are compatible with many years of active life. Auricular fibrillation means a serious mechanical defect, which is an important factor in inducing heart failure. Heart-block, except when due to a temporary toxic cause, is always grave. Alternating pulse is prognostic of death within two years. The recognition of the first two types in young persons should prevent us in the future from alarming a patient, already nervous, by the vague but terrifying diagnosis of weak heart. The irregularity will probably subside after adolescence. This explains those cases in which patients say that they have had a ' weak heart ' for years, and nothing can be found on examination.

Treatment.—In the light of the new evidence as to cardiac rhythm, the action of drugs ordinarily used for diseases of the heart has had to be reinvestigated. The data are still insufficient, but some conclusions have been arrived at.

Digitalis is by far the most potent of these drugs, but it is a two-edged sword, and very unsatisfactory results may follow its use in unsuitable cases in animals. Besides its action on the heart, it has a pronounced effect upon the bloodvessels, causing vaso-constriction,

and therefore a rise of blood-pressure. Recent observers have failed to find this vaso-constrictor action in human beings. Still, it seems to me not to give satisfactory results when the pressure is high, and, indeed, Withering, when he introduced the drug, did not advise its use in the type of case which we now know has a raised pressure. In such circumstances I prefer strophanthus, or with the digitalis a slowly acting vaso-dilator, such as erythrol tetranitrate, ½ grain, or mannitol nitrate, 1 grain, every six hours. In my opinion the blood-pressure ought to be determined in every case.

Turning from the vessels to the heart, we have to distinguish between the action of the drug on conductivity, on tonicity, and on contractility. On *conductivity* digitalis often has a depressing effect; Mackenzie has shown that it causes a delay, and sometimes a stoppage, in the transmission of the impulse from auricle to ventricle. Conduction is such an important function of the auriculo-ventricular bundle that, when this structure is involved, as in partial heart-block, digitalis is contra-indicated. In many cases of heart-block the blood-pressure may be quite high, although the arterial pulse is so slow. Gibson has seen three cases in which the pressure ranged from 210 to 270 millimetres. In one such case, where the radial pulse was 32, while the venous pulse was 64, I found that the blood-pressure was more than 300 millimetres.

On the other hand, when auricular fibrillation is

found in mitral stenosis, digitalis is a most useful drug. Here the thinning of the auricular muscle interferes with the passage of the wave; the bundle itself is not at fault. This is remedied by increasing the tone of the auricles. The most striking and immediate benefit I have ever seen from digitalis was in a case of mitral stenosis with auricular fibrillation. Mackenzie believes that the drug owes its reputation to its remarkable action in these cases. This is because the greatest effect of digitalis is on *tonicity*. In the acute dilatation of febrile affections, however, it has no effect, and not much on the dilatation secondary to cardio-sclerosis. Cushny says, 'In cases of dilatation with weak and insufficient systole, its action is almost specific. This is true, whether one or both ventricular chambers are affected, so long as the cardiac muscle has not undergone degeneration.' Coupled beats are a sign to stop or to lessen the dose of digitalis.

On *rate* it has very little action, except where rapidity is due to dilatation. On *contractility* it occasionally has a depressing effect.

We may classify the reaction of the different types of irregularity to digitalis in tabular form as follows:

Digitalis is indicated in	Digitalis is of no use in	Digitalis is contra-indicated in
Auricular fibrillation.	Sinus irregularity.	Incomplete heart-block.
Auricular flutter.	Ventricular extra-systoles.	Pulsus alternans.
May be indicated in	Paroxysmal tachycardia.	
Complete heart-block.	Toxic myocarditis.	

Strophanthus is not so readily absorbed as digitalis, but intravenous injections of strophanthin produce a very powerful effect. A dose of $\frac{1}{250}$ grain may be given in a little saline, and repeated in two hours, and then in four hours. It should not be used in urgent cases, as it is not free from risk, and if digitalis has been recently given, it is very dangerous.

The action of the caffein group and of strychnine has already been considered under heart-block.

This is not the place to attempt to deal with the treatment of cardiac arrhythmia in general; my object is simply to call attention to certain modifications in our ideas which result from our fresh knowledge of the functions of the cardiac muscle.

The Athletic Heart.

Though perhaps not falling strictly in the category of irregular hearts, it will be worth while to consider briefly the effect of excessive exercise upon the heart.

Until lately exact knowledge on the subject of the 'athletic heart' has been lacking. This has now been provided by R. W. Michell (Allbutt and Rolleston's 'System of Medicine,' vol. vi., p. 199), who has carefully studied the effects of exercise on Cambridge undergraduates. His experience is based on repeated observations of 1,200 rowing men, 410 football players, and a few running men. He concludes that habitual athletic exercises cause a progressive reduction in pulse-rate, 48 or even 40, and a gradual increase in

the size of the left ventricle. The percentage of men showing this reduction increased with each successive year of residence at the University. Habitual athletics also affect the difference between the pulse-rate in the morning before exercise and that in the evening after exercise; this becomes less marked. The first sound of the heart changes in character, being represented more exactly by the sound 'l—lump' than by 'lub.' The pitch of the first sound is lowered, but its volume is increased, and its beginning is smaller than its continuation. The blood-pressure shows a tendency to rise. The red blood-corpuscles increase to 6,000,000, with a corresponding increase in the colour-index. A drop in the blood-count and colour-index is the earliest sign of 'staleness' in a trained man. Probably many physicians, on finding a youth with signs of hypertrophy of the heart, an altered first sound, bradycardia, and a raised blood-pressure, would hesitate before accepting him as a first-class life. It is important to realize, therefore, that this condition may be entirely physiological. The effect of a febrile attack on such a heart is curious. A pulse-rate of no more than 70 may be found at the onset of even a severe fever. At the end of forty-eight hours the rate suddenly increases without necessarily meaning that the patient is worse. Presumably the physiological reserve is becoming exhausted. After recovery the heart has the rhythm and rate of the normal non-athletic heart, and some weeks or months of training must elapse before the old conditions are restored.

Michell takes the following signs as indications of overwork of the athletic heart:

(1) A rise in the morning pulse-rate before exercise. This is the earliest sign.

(2) The increased blood-pressure produced by exercise persists longer.

(3) The heart-sounds begin to 'space out,' so that there is an approach to equalization of intervals between the sounds. This shows that rest is imperative.

(4) The apex-beat goes out, and stays out, at the extreme point of the cardiac dulness.

A curious symptom is great sensitiveness of the heart's apex to pressure. The patient feels as if he would vomit when the stethoscope is pressed against the chest over the apex-beat.

The earliest signs of recovery are the return of the apex to its normal position and a fall of blood-pressure. The treatment which Michell has found best is rest combined with diuretin in 15-grain doses, and hot baths or a hot pack. The great advantage he claims for this drug is that it lowers blood-pressure by relaxing the bloodvessels, not only without depressing the heart, but with a distinct increase in the volume of the first sound. It has not a cumulative effect. Abstention from tea, coffee, cocoa, and tobacco is enjoined, and the quantity of food, both solid and fluid, is restricted. If the rhythm of the heart be greatly disturbed, he gives a hypodermic injection of morphia combined with strychnine. Digitalis alone or with strychnine gives bad results.

Compensation.

Certain physiological principles will help to a comprehension both of the occurrence and of the failure of compensation.

If the cardiac muscle be exposed to an increase of its load, such as occurs when there is a greater resistance to the outflow of blood, it responds by increased energy of contraction. With each addition to its load there is more shortening of the fibres. Of course, there is a limit to this, and, if the load be increased too much, the muscle may fail to respond at all. It has been said that the heart's motto is 'All or nothing': the tendency of the cardiac muscle is to rise to an emergency and do all that is required of it, but, if it be unable to meet the demands in full, to do nothing at all. In this we see the explanation both of compensation and of syncope; the muscle goes on responding until the proverbial last straw proves too much for it.

How great is this reserve force of the heart is seen by the experiment in which a ligature is placed round the pulmonary artery and slowly tightened. The lumen of the artery may be reduced to one-third of its normal size without perceptibly diminishing the output of blood, though the intracardiac pressure will have to rise three- or four-fold. The same thing is observed if the work of the heart be augmented by increasing the diastolic inflow, either by pressure on

the veins of the abdomen, or by injection of large quantities of fluid into the circulation, or by damaging the aortic valves. Within very wide limits, the output of the heart is independent of the resistance (Starling).

Complete failure of the whole heart to respond is exceptional; more usually the failure involves individual fibres. If the peripheral resistance be increased too much, the volume output of the ventricle will diminish, an increasing quantity of blood remaining in the ventricle after each systole. In this way dilatation will result. For continued additional work to be performed, hypertrophy of the cardiac muscle must occur. Its causation is obscure, but one result of the activity of the muscle must be an additional lymph flow, and increased nutrition would lead to increased growth of the cells.

When adequate hypertrophy has produced complete compensation, it may be asked, In what respect is the hypertrophied heart inferior to an ordianry one? It is powerful, and it can meet the demands made upon it, but it is definitely inferior in two points. It is working much nearer to the limits of its power, so that it has much less reserve force, and its capacity for adjusting itself to unusual calls upon it is therefore restricted. It is, in fact, a spendthrift heart, while a dilated heart is a bankrupt one. Secondly, the auriculo-ventricular bundle does not hypertrophy with the rest of the heart, and a strand which may be adequate for the conduction of normal impulses may

prove unequal to the continued carrying of the more powerful impulses which are now necessary.

Though the heart can adjust itself so well to increased resistance to its systolic output, it is very intolerant of interference with its diastolic filling. One important factor in this filling is the aspiration of blood into the chest by the respiratory movements. When persons are crushed to death in a crowd they die of syncope, not of asphyxia. Yet it is the compression of the thorax that kills, and children, with their comparatively yielding chests, suffer first. They die because the heart cannot be properly filled. Again, rupture of an aneurysm of the first part of the aorta into the pericardial sac may be immediately fatal, though only 6 or 8 ounces of blood are extravasated in some cases. No one dies from such a small loss of blood as that; death is not from hæmorrhage, but from the sudden rise of intrapericardial pressure, which prevents the diastolic filling of the heart. In pericardial effusion the accumulation of fluid is not so rapid, so that the heart has time to accommodate itself to some extent; but here, too, its action is seriously embarrassed. A probable explanation of the contrast is that interference with the diastolic filling strikes at the very origin of the rhythm in the sino-auricular node, and deprives the heart walls of that tension which is so powerful a stimulus to contraction.

CHAPTER XII

THE VASOMOTOR SYSTEM IN DISEASE

The introduction of precise methods of registering blood-pressure in clinical work has naturally directed much more attention to the part played by the vasomotor system in disease.

Briefly, the functions of the vasomotor system are two—to regulate the general blood-pressure, and to regulate the local blood-supply. These functions are carried out by the following structures:

1. **The Vasomotor Centre,** beginning 1 or 2 millimetres below the corpora quadrigemina, and ending 4 millimetres above the calamus scriptorius. But there must also be secondary centres in the cord, since asphyxia can still produce a rise of blood-pressure after the medullary centre has been cut off, though not after the spinal cord has been destroyed. There is, further, some degree of local vasomotor control, since some recovery of tone may occur after complete separation of the vascular area from the central nervous system. This is probably due to the usual effect of stretching plain muscle—namely, that it contracts more forcibly.

2. **Efferent Nerves,** which can either constrict or dilate the vessels.

(*a*) *Constrictors.* — These are much the most numerous, and are confined to the sympathetic. Leaving the spinal cord in the anterior roots of the second thoracic to the second lumbar nerves, they pass into the sympathetic chain by the white rami communicantes, and end around a nerve cell in the first ganglion they reach. Here a new non-medullated ' postganglionic ' fibre starts, which is distributed to its appropriate destination. This is the method of distribution, whatever the part of the body to be supplied.

(*b*) *Dilators.*—These are not nearly so numerous. The muscular coats of the bloodvessels being always partly contracted, it is possible for dilatation to be produced by inhibition of a constrictor. Pure dilator nerves will, therefore, only be found where there is a special need for marked and rapid dilatation. Thus the chorda tympani nerve carries dilator fibres to the submaxillary gland, and the auriculo-temporal nerve to the parotid. The nervi erigentes form part of the pelvic visceral nerve springing from the second and third sacral roots. All these belong to the *parasympathetic* system—*i.e.*, those fibres with visceral functions which leave the central nervous system above the cervical or below the lumbar plexus. Unlike the constrictors, they have their ganglionic station close to their destination.

The existence of dilator fibres, also, in mixed nerve

trunks has been proved by taking advantage of the fact that constrictors degenerate more quickly after section, and are more readily affected by cooling than dilators; on using slow, rhythmically repeated shocks (one per second) a dilator effect can be obtained, whereas rapidly interrupted shocks would excite the constrictors.

Dilator nerves to the limbs have appeared in a new aspect, however, since Bayliss has shown that they seem to be in every way identical with the sensory nerves. Under experimental conditions, at any rate, these fibres are able to carry ' antidromic ' impulses—that is to say, the same fibre is able to convey sensory impulses towards the brain and dilator impulses towards the periphery. This is a disturbing fact, because opposed to our fundamental conceptions of the functions of the anterior and posterior roots, but it cannot be neglected on that account. The missing link in the evidence at present is the way in which these fibres are connected to the muscular coats of the vessels.

3. **Afferent Nerves.**—Impulses may pass to the vasomotor centre calling for a general rise or fall of blood-pressure. While the efferent nerves may produce either a local or a general effect, the afferent can only produce the latter. They are of two kinds:

(*a*) *Pressor*, producing a rise of blood-pressure. All sensory nerves are pressor in their action, causing the vasomotor centre to throw out increased constrictor impulses, particularly to the splanchnic area.

This explains the rise of pressure which may be seen in all painful conditions. It has the effect of increasing the blood-supply to the brain; at the same time vaso-dilatation occurs at the site of the painful stimulus through the antidromic fibres. In this way the blood-supply is simultaneously increased at the point where the painful stimulus is *received* and where it is *perceived*, thus facilitating the appropriate reaction in each case.

(*b*) *Depressor*, producing a fall of blood-pressure by causing the vasomotor centre to relax the normal constrictor tone in the splanchnic area, which thereby becomes flushed with blood. The only pure depressor nerve is the depressor branch of the vagus. This may be regarded as a way of escape for the heart, if it be labouring against too high a blood-pressure.

The existence of depressor fibres in sensory nerves may also be demonstrated, since on regeneration after section they recover before the pressors, and on cooling they retain their function longer. Stimulation of the mucous membrane of the rectum and vagina may also produce a depressor effect, especially under anæsthesia.

Failure of the vasomotor system to respond adequately to the needs of the body may result either in insufficient regulation of the general blood-pressure or of the local blood-supply. We will take examples of each.

It is not uncommon to be told by a patient that one of his first symptoms was that, on getting out of bed

in the morning to pass water, he fainted. Normally a change of posture should not produce a perceptible effect on the blood-pressure, the slightest degree of cerebral anæmia at once inducing the vasomotor centre to throw out increased constrictor impulses, which, by tightening up the splanchnic bloodvessels, forces more blood to the head again. In this way the effect of gravity is counterbalanced. But if the vasomotor response is inadequate, the erect posture will lead to cerebral anæmia, and hence to fainting. If the intra-abdominal pressure is lowered at the same time by the emptying of the bladder, this is still more likely to happen. Fainting following the tapping of ascites is due to the same cause, and, as is well known, it may be prevented by tightening up a binder round the abdomen as the fluid escapes, thus avoiding splanchnic engorgement.

During prolonged recumbency the vasomotor centre will lose its promptitude in responding to changes of posture, which explains the faintness that any patient is subject to on first getting out of bed after a long illness.

Insomnia may be due to inadequate control of the general blood-pressure by the vasomotor system. Ordinarily a certain degree of cerebral anæmia plays an important part in inducing sleep. The hypnotic effect of taking some warm fluid or a little food is due to the vaso-dilation it induces in the splanchnic area, thus drawing away blood from the head. Cold feet may help in causing insomnia by keeping too much blood at the opposite end of the body.

Insomnia is often troublesome in conditions of high arterial tension. Apart from measures directed towards the cause of the high tension, we should treat this symptom by propping the head up on fairly high pillows, by flushing the abdominal vessels by a drink of hot water, and by preventing the feet from getting cold.

In 'functional' or orthostatic albuminuria, inadequate vasomotor control, as we have seen, plays an important part. The circulation through the kidney is in consequence retarded by back pressure in the erect posture. Albumen, therefore, is present in the urine secreted in the day, but absent from that secreted while in bed.

Examples of failure in the regulation of the local blood-supply are seen in Raynaud's disease and in erythromelalgia.

At first sight it is not a little surprising that the organs composing the 'tripod of life'—the brain, the lungs, and the heart—either lack or are very scantily supplied by vasomotor nerves. Yet on consideration it will be clear that it is just because they are so important that they cannot be subservient. For we must remember that the vasomotor system can override the local needs for the general demands. The efferent path in a reflex arc is open to impulses coming from many quarters, although the afferent channel is reserved for impulses coming from the particular organ it supplies.

The organs composing the tripod of life cannot allow their local needs to be subordinated in this

way. This may cause them in disease to override the interests of the general economy for their own advantage; though it is merely an example of the survival of the fittest, the most vital organs being protected at all costs.

It is for just such reasons that we find the spleen, a comparatively leisured organ, has its blood-supply most subordinated to the vasomotor system. The splanchnic area plays the largest part in vasomotor effects. Now, it may well be that the stomach or intestines cannot spare their extra blood at a time when vaso-constriction is called for in the general interests of the economy. The spleen is a portal reservoir which will not suffer vitally from a vaso-constriction, and so it is called upon. It is because of its great liability to passive change and of its subordination to the general interests that diseases of the spleen are accompanied by so few definite physiological features. As Frederick Taylor tersely puts it, the spleen is more sinned against than sinning.

The way in which the local needs may be overridden by the vasomotor system is seen in the blanched condition of the skin in the cold stage of fever, and in the dyspepsia that may be produced by severe mental effort during active digestion through blood being forced into the head from the abdominal vessels, which are thus rendered too anæmic.

We may consider some of the results of the exemption of the ' tripod ' of brain, lungs, and heart from the operation of this action of the vasomotor system.

Brain.—Munro, in 1783, enunciated the dictum that the quantity of blood in the cranium is a constant, since the brain substance is incompressible and enclosed in a rigid box. Allowing for variations in the quantity of cerebro-spinal fluid, this is true.

The first effect of a rise of arterial pressure will be to express the cerebro-spinal fluid from the cranium, and then to compress the cerebral sinuses until the pressure in them rises to that which the brain substance exerts against them. Thus the conditions approximate to those obtaining in a system of rigid tubes.

Now, the one part of the brain that must keep up its supply of arterial blood is the medulla, for here are the centres that are essential to life. If the blood supplied be too rich in carbon dioxide, the respiratory centre is excited to increase the respiratory rhythm; if the quantity of blood be not adequate, the vaso-motor centre is excited by the slightest degree of cerebral anæmia to contract the vessels in the great splanchnic pool, and thus force more blood up to the head. There are two ways in which the blood-supply to a part may be increased—local vaso-dilatation, or vaso-constriction elsewhere. In a rigid box a local relaxation of muscular tone would not be very effective, for it might be overridden easily by the intracranial pressure already existing. To force the blood in by a general rise of blood-pressure is to employ a much more powerful mechanism. Thus it is we find that the blood-supply to the brain is mainly

controlled by means of the splanchnic area, which, in its turn, is controlled by the vasomotor centre within the cranium.

This does not mean that there are no vasomotor nerves in the cerebral vessels—such have been found by Morison and by Gulland — and perfusion of adrenalin will cause a slight contraction of these vessels. But it is safe to assert that they must play an entirely subsidiary part, and that all the vasomotor effects ordinarily observed can be adequately explained without reference to them.

To avoid cerebral anæmia, the general blood-pressure must be kept at a point above the intracranial pressure. This was clearly proved by Cushing, who adopted the method of varying the intracranial pressure by introducing normal saline solution into the cranial cavity from a pressure-bottle.

The effect on the general blood-pressure was observed by means of a tracing taken from the femoral artery. Until the intracranial pressure exceeded the blood-pressure, nothing more than a slight quickening of pulse and respiration occurred, and even this could be avoided if the fluid did not interfere with the sensitive dura. But when that point was reached, the blood-pressure was at once raised until it was again greater than the intracranial pressure. This was repeated with each increase of intracranial pressure until the blood-pressure was forced to a level considerably over 200 millimetres of mercury. Then the vasomotor centre began to show

signs of giving way. The splanchnic vessels could be seen to contract every time the brain was compressed, and to dilate again as the pressure fell. If the pressure were raised too rapidly, the so-called major symptoms of compression might be produced—convulsions, evacuation of the bladder and rectum, cessation of the respiration and pronounced vagus effect upon the heart, often causing its complete arrest for from ten to twenty seconds. Then followed a release from this extreme vagus inhibition, and the vasomotor centre began to exert its striking influence. If the vagi were divided before the compression was applied, the blood-pressure could be seen to correspond even more closely than before to the degree of intracranial tension, always remaining slightly higher. If both vagi and spinal cord were thus divided, an increase in intracranial tension did not affect the level of the blood-pressure in the slightest degree, showing that the adjustment is brought about by constriction of the bloodvessels in the rest of the body.

The clinical importance of this in the treatment of cerebral hæmorrhage has been brought out by Leonard Williams.* 'If we reduce blood-pressure—*e.g.*, by venesection or amyl nitrite—to the point at which the reduction will be effective in checking the hæmorrhage, we are obviously in danger of reducing it to the point at which the medulla is starved. There may be a margin of safety—a point to which you

* *The Hospital*, December 14, 1907.

may reduce the blood-pressure so as to moderate the hæmorrhage, without seriously diminishing the supplies to the medulla—but surely this is a razor's edge on which no practical physician will voluntarily choose to tread. The manometer has no information to give us on this crucial point. It tells us, no doubt, that the arterial pressure is very high, but we know that the arterial pressure was high before the accident, and that it is now higher still, because it has to overcome an augmented intracranial pressure; but the instrument does not, and cannot, tell us whether we ought to bleed the patient at all, and, if so, what are the danger-signals. For there are no danger-signals. When the arterial pressure is reduced below the intracranial, death is instantaneous. That venesection may be resorted to in apoplexy not only with impunity, but with conspicuous benefit, is a fact which must be accepted on the testimony of very competent physicians; that it is at best a dangerous expedient, dangerous to the life of the patient and extremely dangerous to the reputation of the practitioner, the above considerations are surely sufficient to show.'

The absolute necessity of maintaining the blood-pressure at a higher level than the intracranial establishes a vicious circle, for the hæmorrhage produces a rise of pressure, and the rise of pressure increases the hæmorrhage. A rising blood-pressure in cerebral hæmorrhage is of very grave prognosis, as it shows the bleeding is still continuing.

Is there any way of lowering intracranial pressure directly? Then the vasomotor centre would allow the blood-pressure to fall; this would assist the arrest of hæmorrhage, and the vicious circle would be broken. Lumbar puncture will diminish intracranial tension, and has, therefore, been recommended in such cases. It has been thought to be risky, in that it will leave the arteries less supported, and therefore more liable to bleed. My answer to this is that as soon as the intracranial pressure is reduced the blood-pressure will fall, and therefore the liability to hæmorrhage is diminished. That the blood-pressure can be reduced in this way I have had the opportunity of observing. A man in whom I had diagnosed cerebral hæmorrhage had a blood-pressure rising from 165 to 210 millimetres. Lumbar puncture withdrew blood-stained cerebro-spinal fluid. The pressure fell at once to 175, and then more gradually to 135 millimetres, while consciousness was soon regained.

Cushing's experiments also explain why we so frequently find more than one hæmorrhage into the brain substance, if the initial one be at all large. If looked for, small hæmorrhages into the pons will be found very commonly in cases of ordinary lenticulo-striate hæmorrhage. It was formerly a puzzle to decide how these were produced, and whether they occurred simultaneously with, before, or after the large hæmorrhage. It is now clear that the large hæmorrhage is responsible for driving up the general blood-pressure so much that diseased arteries in

other parts of the brain are unable to withstand the strain.

Lungs.—The absence of direct vasomotor effects in the pulmonary vessels has some interesting bearings on the treatment of hæmoptysis, which have already been touched upon in the first chapter. It must be remembered, however, that the lung receives blood by another channel also, the bronchial arteries, springing from the aorta. In the hæmoptysis of mitral stenosis the pulmonary vessels alone are involved; adrenalin and other constrictors will therefore do harm by forcing blood from the systemic into the pulmonary vessels. But amyl nitrite will do good, because it will relieve the engorged lung by dilating the systemic vessels. In the hæmoptysis of phthisis, either pulmonary or bronchial vessels may be eroded, though the former are more likely to be implicated, since they are more numerous. But styptic drugs would be inadvisable even if we could be sure that a bronchial artery were the source of the hæmorrhage, for any benefit derived from their local action would be outweighed by the general rise of pressure and by the pulmonary turgescence, which might cause other weak spots to rupture. Nitrite of amyl would still be useful, as the widespread dilatation would draw blood away from the lungs, and thus more than counterbalance the risks of reopening the bleeding-point. Also the lowered pressure would favour the sealing of this point by blood-clot. The same principles would therefore guide us, whichever set of vessels were involved.

Œdema of the Lungs is a common terminal event. In Cohnheim's phrase, a man does not die because he gets œdema of the lung: he gets œdema of the lung because he is dying. It is held to indicate a somewhat rapid failure of the left ventricle, while the right ventricle continues to beat forcibly. As there is no vaso-constrictor action in the pulmonary vessels, there is nothing to prevent engorgement of the lung capillaries, and an effusion must occur into the alveoli. Leonard Williams* has called attention to an acute form of this œdema, and from the correspondence which followed his communication it is clear that the condition is not uncommon, though very inadequately recognized in this country.

A patient usually with high blood-pressure and often with aortic disease is seized, generally while recumbent, with sudden dyspnœa and cyanosis. He becomes greatly distressed, throwing himself about or coughing incessantly. Then a quantity of froth, which has been compared to that of beer, only finer and thinner, and often blood-stained, begins to issue continuously from nose and mouth. Death may occur within a few minutes, and will not be delayed beyond a few hours, if the condition cannot be relieved.

As the heart continues to beat strongly after the patient is apparently suffocated, it might be urged that death could not be from syncope. But it seems likely that the forcible sounds are produced by the

* *Lancet*, December 7, 1907.

right heart. The most probable sequence of events is this: The left heart is already loaded to its full capacity; the proverbial last straw is too much for it, and it breaks down, while the right heart goes on beating still, forcing blood into the lungs until they become engorged, since they are unable to shut off any of the blood-supply by vaso-constriction. An outpouring of serum occurs into the alveoli in such quantities that the patient is drowned in his own secretion. Two facts support this view: the commonest cardiac lesion in these cases is aortic regurgitation, which is known to terminate not infrequently in sudden stoppage of the heart; and venesection (10 to 12 ounces), according to French authorities, is the only effective treatment, and this would relieve the overloaded right heart and the stagnant pulmonary circulation.

Heart.—It is not difficult to understand the absence of vaso-constrictors to the coronary arteries. If a rise of general blood-pressure is produced by vaso-constriction, the heart is given more work to do, so that a better blood-supply must be given to its muscle. If vaso-constriction took place in the coronaries, their blood-supply would be diminished, but in its absence the rise of pressure automatically forces more blood into them. If the heart has less work to do, the pressure falls and the coronaries receive less blood. In this way the supply to the heart muscle is made proportional to its requirements. The power of compensation is extraordinary so long as the coronary arteries remain supple, but if

they become atheromatous, this means of regulation is frustrated, and compensation breaks down.

The heart's ties with the vasomotor system are most intimate on the afferent side through the 'private path' of the depressor nerve. Through this the heart can always produce a fall of pressure should it find itself embarrassed by a pressure that is too high for it. It might be thought that under these conditions an abnormally high pressure could never be maintained. But so long as the heart can meet the high pressure, there is no inducement for it to call the depressor nerve to its aid. We may safely assume however that when the pressure is kept up at a point at which the heart begins to dilate, a structural change must have occurred in the walls of the visceral vessels which renders them incapable of relaxing in answer to the appeals of the depressor nerve.

On Blood-Pressure.

The vasomotor system is, of course, only one factor in determining the blood-pressure. Its importance lies in its sensitiveness to the needs of the organism; like all nervous mechanisms, it is characterized by the rapidity of its reactions.

The pressure, by which the whole of the vascular system is kept distended with blood, is the product of—

1. The beat of the heart.
2. The peripheral resistance.
3. The elasticity of the vessel wall.
4. The volume of the blood.

1. **The Beat of the Heart.**—While the energy of the heart necessarily originates the pressure in the vessels, an increase in its output will cause a rise in pressure only so long as the size of the arterioles remains the same. Mere increase in frequency also will not raise pressure, unless there is a large amount of blood in the great veins awaiting entrance into the heart, and the peripheral resistance is adequate. Indeed, the nervous mechanisms provide that the pulse-rate will vary almost inversely with the blood-pressure. If the pressure rises to a point at which the cardio-inhibitory centre in the medulla is stimulated, the heart is slowed through the vagus, so that unnecessary work is avoided.

2. **The Effective Peripheral Resistance** is provided mainly by the constriction of the muscular coats of the small arteries, which are chiefly controlled by the vasomotor nerves. That the capillaries can change their calibre under the influence of chemical stimuli is, however, highly probable, and the arterioles themselves are not unresponsive to such. Thus Gaskell showed that the acid products of metabolism would dilate the peripheral vessels, and thus provide for their own removal. In the first stage of high blood-pressure in disease there need be no structural change in the vessel wall, but the muscular coat contracts, presumably under the influence of toxic agents. This is in accordance with the general principle that the important functions are subserved by both a chemical and a nervous mechanism. How essential the nervous

factor is in maintaining the pressure is seen on destruction of the cord, when the vessels lose their tone so completely that the circulation cannot proceed. It is the splanchnic area which has in this way by far the greatest influence on the general blood-pressure.

3. **The Elasticity of the Vessel Wall** tends to equalization of the pressure in systole and diastole. For, as the vessel distends with each heart-beat, the pressure becomes lower, and as it retracts during diastole, the pressure remains higher than it otherwise would do. With loss of elasticity comes a more violent fluctuation. Mark the tendency to a vicious circle. Continued high pressure diminishes elasticity, thus increasing the work of the heart. The heart has to hypertrophy, and each beat produces a still higher systolic pressure in a tube that is becoming more rigid. The sequel must be that either the vessel gives way, forming an aneurysm, or rupturing, or else the heart dilates behind the strain.

From this point of view the formation of an aneurysm may be a conservative measure, though one of a desperate character, to compensate for the raised pressure in an inelastic tube. High pressure is, however, not infrequently present in aneurysm, when, according to Janeway, it is one more element in the already unfavourable prognosis.

4. **The Volume of the Circulating Blood** has within wide limits in the normal animal only a subordinate and temporary influence on mean blood-pressure (Janeway). Its variations can be easily compensated for by the vasomotor system. This limits the useful-

ness of venesection to those cases where the compensating mechanism has become damaged. Thus, if the right auricle is becoming so dilated that the transmission of the wave of contraction to the ventricle is a matter of difficulty, venesection may permit it to regain its tone; or if the responsiveness of the vasomotor system is becoming dulled by arterio-sclerosis or toxic agents, reduction of the volume of the blood by bleeding can diminish tension.

The blood-pressure in health reflects the various physical and mental states; a cold bath, a meal, the smoking of a cigar, an animated discussion, all affect it. Irrespective of such disturbances, there are also small diurnal variations. It might be questioned whether this does not destroy the value of a blood-pressure record. But no one questions the value of a temperature chart which also shows fluctuations not produced by disease. And no one doubts the importance of a pulse record, although nervousness affects the pulse far more than the pressure. The alterations of pressure in disease far exceed these minor changes. It is of course necessary to make the observations under similar conditions and at the same time of day.

The clinical value of observations on the blood-pressure is doubted only by those who have never made them. Unlike many another apparatus, there is no sign of the sphygmomanometer being abandoned by those who have once used it systematically; they only change the form of apparatus as mechanial improvements are made. The finger can detect some

differences in pulse-tension, it is true, though it is often entirely at fault, since it can only estimate total pressure, not pressure per square inch; so can the hand detect differences in temperature. But what opinion should we form of a physician who told us that he only judged of temperature by the hand and scorned the aid of the thermometer?

The best methods of estimating blood-pressure depend on the same general principle—circular compression of the upper arm by an air-pad, adjusted by an armlet not less than 12 centimetres wide, to which a manometer is attached. Air is pumped in until the pulse is obliterated at the wrist, and then cautiously allowed to escape again until the pulse just returns. Janeway regards the moment of return of the pulse-wave as the best criterion of systolic pressure; some observers take the mean between this and the point of obliteration. It is doubtful whether any apparatus, even Pachon's, accurately records diastolic pressure. This is unfortunate, for the diastolic pressure is important, being the charge which the arteries must constantly bear, and from which they cannot escape. A high diastolic pressure wears an artery out more quickly than a high systolic with a low diastolic pressure.

I shall use the term 'blood-pressure' as identical with the pressure recorded by some such apparatus. Opinions differ, however, as to whether this does not represent in reality the sum of the pressure and the resistance offered by the arterial wall. Gumprecht

gives physical reasons for believing that the elasticity of the tube itself does not come into the question, and Janeway concludes that, with the wide armlet, and using the first full return of the pulse as a guide, errors from thickening or calcification of the wall have little significance. This is also held by Leonard Hill, who has devised several ingenious experiments to prove the point. William Russell strongly dissents from this view, and it really does seem almost incredible that the great structural differences which are found in the wall can have no effect. But even admitting that the record is a composite one of the resistance of the wall plus the pressure of its contents, this does not deprive it of its value, and changes of pressure as a result of treatment would still be accurately recorded.

It is impossible to discuss the whole question of blood-pressure in disease within the limits at our disposal, but we may take examples of the way in which its study has enlarged our ideas, cleared up difficulties in diagnosis, and helped in prognosis. This has naturally reacted on treatment.

It has enlarged our ideas on the subject of the 'heart failure' in acute infections. Romberg and Pässler showed that, at the height of an infection, sensory irritation and asphyxia did not produce as large a rise of pressure as usual, while abdominal massage raised it as much as ever. It is the vessels that are paralyzed, not the heart that is damaged. Recognition of these facts should lead us to realize the neces-

sity of attacking the circulation through the vasomotor system when this is at fault, and thus protect the heart from secondary damage and needless or harmful stimulation. Post-operative shock has been ably investigated by Crile and by Lockhart Mummery, who regard it as due to vasomotor paralysis. This part of the subject is, however, still a matter of controversy.

In the light of the knowledge we have thus obtained, it would appear that many of the stimulants employed are quite unsuitable for a condition of vasomotor paralysis. Strychnine acts on the centres, which are already exhausted or intoxicated, and therefore unresponsive. Ether has little or no effect; while brandy, which is a vaso-dilator, can hardly benefit vessels that are already relaxed. Digitalis, which acts on the peripheral vessels as well as on the heart, may be of service. Adrenalin and ergot, which act peripherally, may have an admirable effect in combating this paralysis; while barium salts—*e.g.*, 3 grains of the chloride—and pituitrin, which act directly on the muscle fibre, and not on nerve-endings, are appropriate. An abdominal binder should be applied firmly to prevent accumulation of blood in the now stagnant splanchnic pool.

As examples of the help which has been given in diagnosis, if we are in doubt whether a hemiplegia is due to hæmorrhage or thrombosis, we may appeal to the manometer; in the former the pressure must be high, from reasons already considered, while in the

latter it need not. Grainger Stewart has shown that the fatal issue in cerebral thrombosis is often due to a rise of pressure in the stage of reaction, or as a result of stimulant treatment, which bursts the now softened vessel. In the treatment of cerebral thrombosis, then, we must be very careful not to use any stimulant which will raise blood-pressure.

The fact that perforation in typhoid fever causes a rise of pressure, while hæmorrhage produces a fall, is one that will often be of great value in diagnosis.

In albuminuria, again, the blood-pressure will be an aid to diagnosis. In all forms of nephritis it is usually raised. Mahomed found that in acute nephritis the arterial tension rose even before albumen appeared in the urine. But in 'functional' orthostatic albuminuria, though the pressure fluctuates, it does not rise above normal. As the treatment demanded in the two conditions is quite different, it is essential to be clear which we are dealing with; and the manometer will help us. It will help us also to decide on the relative importance of albuminuria and glycosuria when they coexist.

As to prognosis, the grave import of a continued rise in pressure in cerebral hæmorrhage has already been insisted on. In pneumonia a continued but gradual fall of pressure is the rule. Gibson found that any sudden rise before the crisis implied the onset of some complication, acute delirium being often the immediate sequel, while a sudden fall was a warning of the immediate risk of cardiac (or, as I should prefer

to express it, vasomotor) paralysis. In Addison's disease a steady fall of pressure, despite adrenalin, has enabled me to foretell the imminence of the fatal issue. A rise of blood-pressure in pregnancy is a valuable prognostic sign of the approach of toxæmia.

It is now generally conceded that there is a stage in which the blood-pressure is raised before the structural changes of arterio-sclerosis occur, and the manometer will help us to detect it. To take an example: A busy man nearing fifty years of age, and leading the active life of his time, on walking rather smartly to catch his morning train, finds himself out of breath for some little time afterwards. On arrival at his office he has a difficulty in concentrating his mind on his work, and on rising quickly from his chair at the end of the morning he feels very giddy, and reels a little. Now, a little anxious about himself, he becomes introspective—a rare thing with him—and recalls that small worries have upset him more than they need, that responsibility has been more irksome, and that he has not felt so sure of his judgment. He tells his partner that he thinks he has been out of sorts lately, and is met with the frank reply that it is very likely, for, at any rate, his temper has been shocking. He goes to lunch, and thinks that a whisky-and-soda will put him straight. But it doesn't; it only makes him feel more uncomfortable. He lights a good cigar, and is rewarded by palpitations, instead of the blissful sensations that smoking used to evoke. He remembers now that alcohol and tobacco do not seem to have

agreed with him as they used. By the end of the day his head is aching, and he feels thoroughly worn out. He manages to eat a very good dinner as usual, however, and begins to shake off some of his fears. But his night's rest is disturbed, and next morning he feels very 'bilious,' or perhaps he has a return of the neuralgia that has been troubling him of late. It will be a good thing for him now if a violent attack of epistaxis occurs, if only to send him to his doctor. The doctor takes a heavy responsibility upon himself if he simply reassures him, tells him he is run down, prescribes some strychnine, advises a good piece of steak for lunch, and some fine old port after dinner. A more careful examination would certainly have revealed an accentuated second sound at the aortic base, and a blood-pressure of 160 to 180 millimetres; possibly also a trace of albumen, with granular casts in the urine.

The responsibility is all the greater because this man is still in the stage when treatment can be effective; and he is more likely to abide by it than the lower type of patient, 'full of coarse strength, butcher's meat, and sound sleep, who will suspect any philosophical insinuation, or any hint for the conduct of his life which reflects upon this animal existence.'

Perhaps it is even better for him if the danger-signal takes the form of an attack of hæmaturia, for he is not likely to try home remedies for this, as he may for epistaxis; nor is there much fear of the doctor treating it so lightly.

This may be simply the stage of increased blood-

pressure, without structural change, produced by toxic agents. If in this stage the patient takes less meat and no alcohol, gets more oxygen into his lungs and a better evacuation from his bowels, leads a simpler and less strenuous life, an improvement in his blood-pressure and his general condition will follow.

If this high pressure continues, a structural change will ensue. Dixon has shown that any drug which considerably raises blood-pressure will cause degeneration of the middle coat of the arteries in a healthy animal. This might happen because the same drugs which raised pressure were toxic to the arteries, or because the rise of pressure mechanically damages the wall. That the latter explanation is the correct one has been shown by Harvey, who, by merely compressing the aorta of rabbits with the fingers for two or three minutes daily, thereby raising the blood-pressure 30 to 40 millimetres, produced degeneration of the aorta above the point of compression without causing any change in the vessel below.

Tobacco is known to raise blood-pressure, and it might be thought to play a part in the much greater frequency of arterio-sclerosis in men than in women. But tolerance is easily acquired. If a man unused to tobacco smokes a cigar, his pressure first rises 10 to 25 millimetres, and then, after a quarter or half an hour, if the smoking has been continued, drops 30 to 50 millimetres, or even more. The habitual and moderate smoker under similar conditions shows no change beyond a slight rise of 4 or 5 millimetres.

According to Emerson Lee, this immunity is brought about by the production in the liver of some substance —probably a ferment—that destroys the nicotine. We therefore cannot throw much of the responsibility for arterio-sclerosis on to tobacco.

We have but a hazy notion as to the nature of the toxic substances concerned, though Barger and Dale's discovery of putrefactive bodies which raise blood-pressure has helped to clear up our ideas on the subject. The course of events may be pictured somewhat as follows: The toxin, whether formed by perverted metabolism or absorbed from the bowel, irritates the muscular coats of the smaller vessels to contraction, particularly in the splanchnic area, where it will be present in the highest degree of concentration. Finally, it is excreted by the kidney. If this condition be allowed to continue, and the irritated vessels maintain their contraction, muscular hypertrophy must occur here as elsewhere when increased work has to be done. The new muscular tissue soon undergoes degenerative changes. The increased peripheral resistance thus brought about necessitates, for similar reasons, hypertrophy of the heart. The kidney has to excrete the toxin, and suffers in the attempt, so that interstitial nephritis is apt to follow. The pressure has now to rise still more, causing more cardiac hypertrophy in order to drive enough blood through the remaining glomeruli for urinary excretion. Even so elimination becomes defective, and the toxin is therefore kept in more prolonged contact with the tissues it is damaging.

Thus, the diffuse arterial change steadily progresses. On this view the cardiac hypertrophy is purely secondary. Allbutt protests 'against the accusation of these striving hearts of complicity in the arterial disease. . . . They are stout and faithful to the end, even in defeat.'

Allbutt's convenient classification of arterio-sclerosis may be adopted. Excluding chronic Bright's disease, he holds that it is met with clinically in three forms, which, if superficially alike, are very different in nature and causation:

(*a*) *Toxic*, due to lead; to certain of the infective diseases, such as syphilis; to diabetes, and so forth.

(*b*) *Involutionary*, a senile degradation, which may appear before 'three-score years and ten.'

(*c*) *Secondary* or *hyperpietic*, the consequence of tensile stress, of excessive arterial blood pressure persisting for some years.

The type previously described corresponds to (*c*) on this scheme. In the others there is not necessarily a rise of pressure, and we can probably refer the apparent rise, as registered by the manometer, to increased thickness of the walls. The so-called '*rise of blood-pressure in later life*,' occurring in healthy individuals, is probably due to this, and is merely an expression of that loss of elasticity which is characteristic of advancing years. The distinction between the cases in which there is a real rise of pressure and those in which there is not is a practical one. For, to quote Allbutt again, involutionary arterio-sclerosis "results rather in the contraction of the spheres of mental and

bodily activity than, as with hyperpiesis, in the imminence of the fell sergeant Death—death by apoplexy, by cardiac defeat, or by intercurrent acute pneumonia.'

Treatment of High Blood-Pressure.

It must be borne in mind that when there are organic changes in the arteries or kidneys, the blood-pressure must be higher than normal for an adequate circulation to be maintained. In the 'pre-sclerotic' stage we should pay more attention, as Osler urges, to the peripheral field of the circulation. 'Obstruction in the fields can be overcome, to a certain point, but it is cheaper and safer to clear out the weeds. . . . We too often tinker at the pump and the mains, instead of looking at the seat of trouble in the fields.' The abiding difficulty in the treatment is that we do not know what degree of raised pressure is necessary for any degree of arterio-sclerosis, but we do know that the problem has to be met by putting the patient into the way of physiological righteousness rather than by depressor remedies.

The diet should be regulated; the bulk and number of the meals should be reduced; roasted meats, soups, and gravies should be avoided, while fruits, green vegetables, farinaceous and non-nitrogenous foods may be given freely. The salt usually added at table should be stopped, and in severe cases a salt-free diet may be advisable for a time. A pure milk diet is most useful in high-pressure cases when combined with

rest. It should be tried for a few days during periods of increments of pressure. Coffee, tea, tobacco, and alcohol should be limited, and in certain cases excluded. It is best to separate fluids from the solids, or to allow them only at the end of meals.

A warm bath taken daily on rising is a valuable adjunct to treatment. Cold bathing should be avoided. Artificial Nauheim baths, the material for which can now be readily obtained, will lower pressure but I am not satisfied as to their advisability, as they act by vaso-dilatation. An annual course of balneological treatment is often useful. Plombières douches are recommended where there is suspicion of intestinal intoxication. These patients generally do best in a warm, equable climate for the winter.

Exercise in the open air, without strain, and not carried to the point of affecting the pulse or respiration, is followed, as a rule, by a fall in blood-pressure. A life of undue rest should be avoided, but half an hour's complete repose after the midday and evening meals should be enjoined.

These patients are apt to become unduly anxious, and their fears should be allayed as far as possible. As a rule, they should not be told the pressure reading. Particularly they should not read the index themselves, as this alone will send it up.

A free action of the bowels is, of course, imperative, since constipation increases arterial pressure both mechanically and chemically.

Potassium iodide should be given for a time, with

the view, as Leonard Williams says, ' of ferreting out such of the toxins as seem to lurk in the lymph spaces.' There is still too great a tendency to employ nitrites, which simply lower pressure by vaso-dilatation. This is, perhaps, not to be wondered at. In the early days of antipyretic drugs there was a similar tendency to indiscriminate lowering of the temperature. It is so pleasant to see some objective result from our treatment. But the rise of pressure is a symptom just as surely as a rise of temperature, and to lower either without due consideration is to side with the toxin rather than with the patient.

Sometimes hyperpiesis has to be treated, however, just as hyperpyrexia has, irrespective of the cause. Then we should select those vaso-dilators whose action is slow and prolonged. Matthew (*Quarterly Journal of Medicine*, vol. ii., p. 261) found that the fall produced by amyl nitrite was too brief to enable him to register it with the manometer. It is therefore only useful in anginal attacks. Nitro-glycerine only lowered the pressure for forty minutes. Erythrol tetranitrate, on the other hand, in $\frac{1}{2}$-grain doses produced a fall lasting six hours. The great drawback to its use is, however, its liability to induce severe headache in some patients. Mannitol produces a prolonged effect also. Oliver recommends a tabloid prepared for him by Burroughs and Wellcome, having the following composition: Sodii nitrit., gr. $\frac{1}{2}$; erythrol tetranitrit., gr. $\frac{1}{4}$; mannitol nitrit., gr. $\frac{1}{4}$; ammon. hippurate, gr. 1. One or two of these tabloids (designated

'tabloid sodii nitrit. co.') may be taken for lengthened periods, if omitted for a few days or a week in each month. In one case the pressure fell in seven days from 210 to 160, and was still found to be 160 after twelve months' treatment.

There is a great difference in the response to treatment. In some cases the results are remarkably good, and patients have been restored to years of useful and active life.

CHAPTER XIII

ON CYANOSIS

The essential cause of cyanosis is deficiency of oxygen in the red corpuscle, while the essential cause of dyspnœa is excess of carbon dioxide or some non-volatile acid in the respiratory centre. It will follow that, although these two conditions are often associated, this is not necessarily the case. Thus in uræmia we may see dyspnœa without cyanosis, whereas in congenital heart disease cyanosis occurs without dyspnœa. As Lewis points out, if a patient is urgently breathless and an equivalent cyanosis is not found, the dyspnœa is not wholly due to deficient aëration of the blood. He believes non-cyanotic dyspnœa to be produced by the presence of abnormal acids in the blood, such as lactic acid in various conditions and oxybutyric acid in diabetic coma.

A chemical change, then, which results in the hæmoglobin combining with less oxygen, is the immediate cause of cyanosis. But in coal-gas poisoning the corpuscle contains less oxygen, and yet there is no cyanosis. The new compound carboxyhæmoglobin is a bright cherry-red. Again, in methæmoglobinæmia

the corpuscle contains as much oxygen as normal, and yet there is marked cyanosis. We can distinguish two groups of cases, toxic cyanosis and true cyanosis. True cyanosis—*i.e.*, one due to simple reduction of the oxyhæmoglobin—is usually associated with an increase in the number of the red corpuscles. In all cases of cyanosis in which the corpuscles are decreased, or even not increased, a toxic cause should be suspected.

Toxic Cyanosis.—In Chapter X. it was shown that nitrite-producing microbes in the intestine may cause methæmoglobinæmia or sulphæmoglobinæmia, which may lead to a striking degree of cyanosis. Certain coal-tar drugs may also be responsible for the former condition. Either can readily be detected by the spectroscope. It is needless to repeat what has already been said, beyond urging the necessity of diagnosing these conditions from true cyanosis.

True Cyanosis.—Nature's method of compensating for defective oxygenation of existing corpuscles is by adding to their number. Thus prolonged residence at high altitudes, such as Quito in Ecuador, results in polycythæmia. The diminished oxygen tension at that height necessitates an increase in the number of oxygen-carriers, so that, though each is capable of carrying less, the total amount of oxygen carried to the tissues remains the same. Applying this to diseases associated with polycythæmia, we should expect to find that defective oxygenation enters into their causation.

Erythræmia (Splenomegalic Polycythæmia).—The most striking example of increase in the red corpuscles occurs in the condition first described by Vaquez in 1892. Our knowledge of this disease has been added to by the observations of Osler, Saundby and Russell, and Parkes Weber. The patient is usually in the middle period of life. He is generally, though not invariably, cyanosed, but there is no respiratory distress. The eyes may be prominent and the conjunctivæ suffused. Examination of the blood shows that the red corpuscles are increased from the normal 5,000,000 to a figure varying between 8,500,000 and 12,000,000 per cubic millimetre, while the hæmoglobin is raised to 120 or 150 per cent. The white corpuscles are usually increased from the normal 8,000 to 20,000 per cubic millimetre, but in some cases are actually diminished. The viscosity of the blood is naturally considerably increased. The spleen is usually enlarged; sometimes it is greatly enlarged, but then infarcts or tubercles have usually been found. The urine frequently contains a trace of albumen. Pigmentation of the skin has been noted. The most prominent symptoms are torpor, both mental and physical; a sensation of fulness in the head, with headache and vertigo, and in some cases nausea and vomiting. As Osler has pointed out, these symptoms remind us of those to which mountain-climbers and aeronauts are liable. There are also certain vasomotor symptoms. If any part be rubbed it goes red, and if the patient gets hot the general cyanosis is apt

to be replaced by a general flushing. A dependent part becomes blue, but if it be held up it may become pale. The vessels must be very full, for the volume of the blood is increased. Now the capacity of the vessels may be increased by relaxation of the vasomotor tone, and this loss of tone causes the effect of gravity on the circulation to become more pronounced. By the relaxed state of the vessels we can also explain the fact that the blood-pressure is not necessarily raised, although the vessels are so turgid.

The increased viscosity of the blood is a necessary result of its concentration by excess of red corpuscles. Gustav Mann has calculated that the maximum number of corpuscles which the blood is capable of holding in each cubic millimetre is 13·9 millions. A blood-count of 12,000,000 implies, then, a very great increase in the viscosity of the blood, and therefore a considerable delay in the circulation time through the capillaries. This has been experimentally demonstrated. Anything which increases the stay of the blood in the capillaries allows of the abstraction of more oxygen from it. We should therefore expect that this cause of cyanosis would be diminished in part by stimulating the rate of the circulation by warmth and friction, as is actually the case.

The polycythæmia remains to be explained. That it is possibly compensatory is suggested by the increase in the erythroblastic tissues in the red marrow. The enlargement of the spleen is perhaps to be explained in the same way; it may resume its fœtal blood-forming

functions. The other alternative is that its enlargement is purely passive from the relaxed state of the muscular coats of its vessels. Increase of the red marrow may be due to excessive destruction of blood-corpuscles, as in pernicious anæmia. But in erythræmia there is no evidence of hæmolysis, and the excess of red cells might be compensatory for difficulty in oxygenation somewhere. This might be due to—

1. A defect in the taking up of oxygen in the lungs.
2. The presence of a reducing agent in the blood.
3. A difficulty in the taking up of oxygen from the blood by the tissues.

The first is the cause of cyanosis in pulmonary diseases, but cannot be the cause here, since in that case increased rate of circulation would increase the cyanosis by diminishing the time for oxygenation in the lungs.

As to the second possibility, Boycott found the percentage oxygen capacity of the hæmoglobin normal, though in one instance it was slightly lessened. And even in that case the total oxygen capacity was at least 10 per cent. above normal, owing to the excess of hæmoglobin. A single case with a normal percentage oxygen capacity is incompatible with an abnormal reducing agent in the blood.

There remains the third explanation: some difficulty in the taking up of oxygen by the tissues. Now, the materials out of which the tissues are made are comparatively stable, not being oxidized readily; yet the tissues have an extraordinary avidity for oxygen. How are we to explain this apparent paradox? From

normal tissue cells ferments called oxidases can be extracted, which are capable of effecting oxidations. Given a diminution in these oxidases, all the rest follows inevitably—oxygenation of the tissues would be defective, which would increase the demand for red corpuscles. Hence the polycythæmia and the increase in the red marrow and the spleen. The excess of corpuscles would increase the viscosity of the blood, and this in its turn would delay the circulation. Cyanosis would occur only when the delay is sufficient to allow of the tissues being able to take up enough oxygen, even though they can only do it slowly. The cyanosis disappears when the circulation is quickened in any way, and in some cases—such as one carefully described by Parkes Weber—it is never present. It may be urged against this view that, as the polycythæmia is a compensatory mechanism, it would never occur up to the point of causing cyanosis, since this means an increased and not a diminished reduction. But a compensatory mechanism is never so perfect as a normal one; if it were, it would tend to replace the existing one on ordinary evolutionary principles. The drawback to polycythæmia as a compensatory mechanism is the excessive viscosity of the blood which must accompany it, so that it becomes a difficult matter to provide the oxygen required by the tissues without delaying the circulation too much. If this happy mean cannot be exactly achieved, cyanosis must be caused, but this is less serious than starving the tissues of oxygen.

Parkes Weber (*Quarterly Journal of Medicine*, vol. ii., p. 85) takes a different view, concluding that the change in the red bone-marrow is primary; that there is an overproduction of red cells, just as in myelogenic leukæmia there is an overproduction of white cells.

Treatment.—There is at present no effective treatment for this disease. That oxygen inhalations are no good is only to be expected, as there is no deficiency of oxygen in the blood. Temporary benefit may be derived from bleeding. X rays have been applied to the spleen also, but without much avail, as we might expect, since this is not the seat of the disease. They might be of more service if applied to the long bones.

Cyanosis in Congenital Heart Disease.—The cause of cyanosis in congenital heart disease has provoked so much discussion that it may seem rash to assert that the explanation is fairly simple, if we bear in mind the changes which ought to occur in the circulation at birth.

During fœtal life the circulation is so arranged that the purest blood from the placenta is sent as quickly as possible to the head. To achieve this the liver is short-circuited by the ductus venosus, and the blood entering the right auricle is directed by the Eustachian valve through the foramen ovale into the left auricle. In this process the limbic bands of the auricle assist by drawing the inferior vena cava towards the foramen. From this point the adult course of the circulation is followed to the head. The returning stream enters the heart by the superior vena cava, and passes down

into the right ventricle, being largely shut off from the other stream in the right auricle by the Eustachian valve and the limbic bands. It leaves the right auricle by the pulmonary artery, but as it is unnecessary for all this volume of blood to go to the lungs, it is diverted by the ductus arteriosus into the aorta beyond the origin of the carotids.

It is not correct to attribute the child's first breath to the stimulating effect of exposure to the lower temperature of the outside world, for interference with the placental circulation while the child is still *in utero* will cause it to breathe: and if the child be received into a bath at body temperature, respiratory movements will occur as usual. When oxygenation in the placental circulation is interfered with, carbon dioxide accumulates in the respiratory centre, and produces its usual effect—a stimulus to respiratory movements.

These movements aspirate a large volume of blood into the lungs, which returns by the pulmonary veins to the left auricle. A fall of pressure, therefore, occurs in the right auricle, and a rise of pressure in the left, which helps to close the oblique opening in the foramen ovale. The downward movement of the diaphragm alters the plane in which the limbic bands act, so that they no longer draw the inferior vena cava towards the foramen ovale.

The alterations in pressure also help to close the ductus arteriosus, as the distended aorta now projects within its lumen, and stops the flow through it.

In this way the ordinary post-natal condition is arrived at. But if there be stenosis at or below the pulmonary valves, the mechanism of this change is fundamentally disturbed, though the fœtal circulation will not have been embarrassed in any way. The pressure on the right side of the heart will be too great to allow of closure of the septum between the two sides, so that it remains patent either in its auricular or its ventricular portions. In the latter case there is probably a true congenital defect, a reversion to the type of reptilian heart; while the former is commonly the necessary result of a fœtal endocarditis.

The deficiency in the exit of blood from the right ventricle will be made good to some extent by the ductus arteriosus remaining open. I have seen complete atresia of the pulmonary valves, in which the whole of the blood to the lungs reached them by this route.

Now, mere patency of the ductus arteriosus will not cause cyanosis; neither will simple intermixture of the arterial and venous streams through imperfections in the septum. In a case recorded by Young there was only a trace of an interventricular septum, and yet there was no cyanosis until the heart began to fail. Morison's analysis of seventy-five cases shows that obstruction in the pulmonary artery is the lesion most commonly associated with cyanosis. If sufficient blood cannot enter the lungs, cyanosis is inevitable. That such blood as does go to the lungs is adequately oxygenated is shown by the failure of oxygen inhalations

to benefit the cyanosis. So long as there is free admission of blood to the lungs, cyanosis does not occur, even though the streams mix.

The only way in which the body can compensate for this obstruction of the pulmonary artery is by charging the blood more highly with corpuscles, so that the oxygen capacity of that portion which does reach the lungs will be increased. Polycythæmia is therefore always met with in such cases, and may amount to 8,000,000 or 9,000,000 per cubic millimetre.

It has been contended that the polycythæmia and cyanosis are alike due to general congestion of the venous system from obstruction; but it has probably been the lot of everyone, as it certainly has been mine, to see cases of congenital heart disease with marked cyanosis and a high degree of polycythæmia, in which signs of back-pressure were entirely lacking.

Other causes of chronic cyanosis call for only brief consideration. The other cardiac lesions typically associated with cyanosis are diseases of the tricuspid valve and adherent pericardium. Here the distribution to the lungs is at fault, so that oxygenation is imperfect; at the same time the back-pressure causes a certain degree of stasis in the capillaries, so that the blood there is richer in corpuscles than normal. If œdema be present also, this will increase the concentration of the blood. In this way a moderate degree of polycythæmia is found in the blood obtained from the peripheral circulation. This is spoken of as a relative polycythæmia, since there is not an absolute

increase in the number of corpuscles, but only an alteration in their distribution with respect to the fluid constituents.

Mediastinal inflammation and growths act in very much the same way, by interfering with the diastolic filling of the heart.

Of all pulmonary conditions, emphysema causes the highest degree of chronic cyanosis. According to Osler, cyanosis of an extreme grade is more common here than in any other affection, except congenital heart disease. 'So far as I know,' he says, 'it is the only disease in which a patient may be able to go about, and even to walk into the hospital or consulting-room, with a lividity of startling intensity. The contrast between the extreme cyanosis and the comparative comfort of the patient is very striking. In other affections of the heart and lungs, associated with a similar degree of cyanosis, the patient is invariably in bed, and usually in a state of orthopnœa.' He makes another exception in favour of toxic cyanosis.

In emphysema there is such a gradual diminution of the oxygenating surface of the lung that the discomfort to the patient is reduced to a minimum. There is only a moderate polycythæmia, however. After emphysema, fibroid change in the lung is, perhaps, the most important cause of marked chronic cyanosis. Here again the diminished surface available for respiratory interchange is responsible.

When, in these conditions, the right heart begins to fail, cardiac causes for cyanosis are superadded, and

the dyspnœa becomes marked. Until then the right heart has an extraordinary power, as we saw in Chapter XI., of compensating for increased resistance in the pulmonary circulation. Thus, in pneumonia, cyanosis is much more an evidence of failure of the right heart than of any increase in the consolidation.

Oxygen can produce a striking alleviation of cyanosis in emphysema with failing heart. This contrasts with its failure in congenital heart disease, and provides a further argument against explaining the cyanosis in that condition as due to back-pressure.

Local cyanosis, such as occurs in Raynaud's disease and other vasomotor diseases, need not detain us. Traumatic cyanosis, which is seen in the rare condition of pressure stasis following severe crushes of the chest, has been shown by Beach to be due to mechanical over-distension of the veins and capillaries. True extravasations of blood may occur as well, however, especially in the lax tissues around the eye, where the ordinary changes of colour in bruises will follow.

Conclusions.—Toxic cyanosis is due to a chemical change in the hæmoglobin molecule, produced by drugs or intestinal intoxication, and leading to the formation of methæmoglobin or sulphæmoglobin. It is not associated with polycythæmia, and there may be marked oligocythæmia.

True cyanosis from diminished oxygen in the red corpuscle is typically associated with polycythæmia, which may be—

1. *Absolute* where there is simple failure of oxygenation, either—

(*a*) In the lungs, because some of the blood does not get there, as in congenital heart disease, or because there is reduction in the oxygenating area of the lungs, as in emphysema; or,

(*b*) In the tissues, because they are unable to take up oxygen so readily, as perhaps in erythræmia; or,

2. *Relative,* from anasarca, which causes concentration of the blood, as in failing heart, or in a heart embarrassed by pericardial adhesions, which interfere with its filling.

I would emphasize, in conclusion, the assistance that the blood-count and the spectroscope will give in making the diagnosis on which alone correct treatment can be based.

CHAPTER XIV

VITAMINES AND CALCIUM SALTS

It is recognized that metallic salts play an important part both in the physiology and pathology of metabolism. Thus, retention of sodium chloride is a factor in the production of œdema, and iron plays an essential part in the therapeutics of chlorosis. Indeed, we are constantly using metallic drugs, and modifying metabolism thereby, though in many cases we lack precise information as to how they act. Yet it might be expected that investigations on such points would be simpler to carry out, and more definite in their results, than those on the action of organic bodies, the chemical composition of which is often not completely known.

Forster fed dogs on ash-free fats and carbohydrates, and meats which had been extracted with water. At the end of twenty-six to thirty-six days the animals were moribund.

Lunin found that, whereas mice lived well on a diet of dried cow's milk, they died in twenty to thirty days if fed on the organic but ash-free constituents,

together with the extracted salts of cow's milk. He thought that some at least of the salts must be provided in organic combinations such as are found in vegetable or animal foods.

But it is now known that certain organic substances, present in minute quantities and easily overlooked, play an important part both in growth and disease. These would have been removed by the methods employed by Forster and Lunin. Hopkins found that when food, completely freed from these organic substances by extraction with alcohol, was given to young animals they ceased to grow, although they ate a normal amount. If the extracted material, fresh tissue extracts, or minute quantities of milk were added, the animals grew normally. This may have an important bearing on the dietetic treatment of malignant disease, as its rapid and disordered growth demands more of these substances than normal tissues. Funk found that chickens fed on red rice did not grow. If yeast or powdered sarcoma cells were added, they grew, though not so much as on ordinary diet.

Not only may growth be checked by the lack of these organic substances, but actual disease may be induced, such as scurvy, both in adults and in infants, beri-beri, and perhaps epidemic dropsy and pellagra. Fresh milk contains both an anti-scorbutic principle and one preventing beri-beri. Sterilization of milk destroys this anti-scorbutic principle, so that scurvy may be induced in infants fed entirely on such food. Holst

and Frölich caused a fatal form of scurvy in guinea-pigs by feeding on barley, oats, or rye. Timely addition of fresh potatoes, apples, carrots, cabbage, or lime-juice would cure the disease. These fruits and vegetables were useless in the dried form, and their expressed juice lost its activity on heating or long standing. Lime-juice, however, was an exception, for it did not lose its activity if boiled for an hour; this explains its great value as an anti-scorbutic in the days of long voyages without fresh food. Funk has given the name of *vitamines* to such substances, and believes them to be crystalline in form and basic in chemical constitution. To the beri-beri vitamine in the outer layer of rice he has assigned the formula $C_{17}H_{20}N_2O_7$. He has also found it in milk, yeast, ox-brain, and lime-juice.

There are probably similar substances in meat extracts which accelerate growth (Thompson and Caldwell). It may therefore be necessary to revise our estimate of the value of beef-tea. Its nutritive value is negligible, but there may be, after all, some grounds for the popular confidence in it. As Hutchison points out, the value of oatmeal in some cases of diabetes may be due to its containing a vitamine, while the controversy as to the relative merits of white and wholemeal bread assumes a new aspect. Evidently a diet is not necessarily adequate because it is sufficient in caloric value and protein content. He maintains that this should confirm our belief in a mixed diet, drawn from as many sources as possible, and dis-

courage fads, extremes, and one-sided views and practices in dietetic matters.

Special interest has been taken in the rôle of calcium in the body, and many theories, not always well founded, have been based thereon. Some interesting therapeutic results have, however, been obtained.

In one sense, calcium may be regarded as a very inert substance, as it is deposited in largest amounts in normal tissue, with a sluggish metabolism, such as bone, or in any dead tissue which is not infected, but is so large or so situated that it cannot be absorbed. The percentage of calcium may be almost exactly the same in either case. Muscles showing the reaction of degeneration contain an excess of calcium salts, as do retrogressing malignant tumours. Degenerated or necrotic ganglion cells of the brain become infiltrated with calcium salts until a complete cast is formed, with dendrites and axis cylinder infiltrated alike (Wells). Calcification in quiescent tuberculous masses and the deposit of calcium in areas of fat necrosis illustrate the same thing.

The replacement of elastic tissues by calcareous material is a characteristic feature of growing old, and is well seen in arterial degeneration, which is in a sense a form of premature senility.

The part played by calcium in the clotting of blood —a change which signifies its death as a tissue—might be regarded as another example, but the calcium only renders the fibrin ferment active, and does not form an essential part in the resulting clot.

But all the activities of calcium cannot be disposed of so summarily; for calcium salts are essential to the heart-beat, and indeed, if they were simply inert, no bad result would follow their removal from the diet. But calcium is constantly leaving the body in the excretions, and it must be replaced. Not only is it excreted in the urine, but Voit found that it was also eliminated by the bowel in small amounts—about 0·15 to 0·16 gramme a day. Some consider the excessive drain of calcium salts in diabetes as a factor in producing acid intoxication. This all points to an active function for calcium salts in metabolism.

Lime-salts are absorbed with difficulty, and appear to retard also the absorption of the fluid in which they are dissolved. The most striking effects of altering the calcium content of the diet are found in connection with the curdling of milk and the clotting of blood; these will therefore be dealt with first.

Calcium and the Curdling of Milk.—The curdling of milk takes place in two stages: first, the rennin of the gastric juice converts the caseinogen into soluble casein; then the calcium salts present precipitate the casein in a soluble form. If the calcium salts be removed, this precipitation does not occur.

Now, in the feeding of infants on cow's milk, one of the disadvantages is that the curd is tough and massive, quite unlike the much finer flocculi formed in human milk. As cow's milk is richer in proteins than human milk, this can be remedied to a certain extent by dilution; but in that case the carbohydrates

and fats are reduced too much, as is seen from the following table by Poynton:

	Human Milk.	Cow's Milk.		
		I. 1 of Milk to 2 of Water.	II. Equal Parts.	III. 2 of Milk to 1 of Water.
Proteins	1·5	1·0	1·5	2·0
Fats	3·5	1·3	2·0	2·8
Carbohydrates ...	6·5	1·6	2·5	3·3

Thus simple dilution may mean under-nutrition. This can be corrected by addition of sugar and cream, but the method is a little troublesome, and does not altogether avoid the objectionable formation of a tough curd.

Cow's milk contains six times as much calcium as human milk, so if we can remove some of this we need not dilute the milk so much. Oxalates and fluorides, which were first used to precipitate calcium, are poisonous, and cannot be used. Wright found that citrates, which are harmless, had a similar action. According to Martin, citrate of soda acts by forming a double salt with calcium, which is not available for curdling of milk or clotting of blood. This has the additional advantage that the calcium not being removed entirely is still available for other purposes in metabolism.

If 3 grains of sodium citrate be added to each ounce

of milk, there is only a very fine curd; and 2 grains, or even 1, will markedly diminish its cohesion. The sodium salt is more effective than the potassium salt. The method is simple, for the salt is freely soluble, and the required amount can be prescribed in a drachm of water, to be put in each feed of milk. A little chloroform water should be added to a bottle that has to last a week, to prevent fungus growing in the dilute solution.

In such doses it scarcely alters the taste of the milk at all, and, as it is a neutral salt, it does not tend to inhibit gastric secretion as do the alkaline salts.

Poynton sums up its advantages as follows: It renders the curd of cow's milk more easily digestible; it is cheap, convenient to handle, easy to control, and progressive in principle. It allows the milk to be given in a more concentrated form, and thus avoids to some extent the risk of under-feeding; there is no danger of scurvy; it gains the confidence of the mother, who naturally believes in medicines. Besides employing it in dyspepsia, he uses it as a routine for weaning a healthy infant on to cow's milk, gradually diminishing the amount of citrate. He does not find it of value in the rare cases of complete intolerance of cow's milk, in severe cases of gastro-enteritis from impure milk, or in organic diseases, such as congenital hypertrophic stenosis of the pylorus. In the last case, however, I think it may be a useful adjunct to other methods, as it is essential to prevent the formation of any lumps in the stomach.

It is called for whenever undigested curds appear in the stools. Apart from other reasons to be considered presently, it should be used in typhoid fever in such circumstances. Our treatment of this disease is often fallacious in that we regard too much the condition of the food when it enters the mouth, rather than its condition as it passes over the ulcers; it is clear that many solid foods are fluid by that time, while milk, though liquid when swallowed, will form curds that may irritate the ileum.

The practical success of this method raises doubts as to the physiological advantages of curdling in general. It is usually claimed that, did curdling not occur, the milk would pass along the intestine too rapidly, and thus escape unabsorbed; but, as a matter of fact, we find that milk may be absorbed more completely when it is thus prevented from curdling. Pancreatic juice contains a milk-curdling ferment, but if the juice be active no curd is seen, because the trypsin will digest it as fast as it forms. On the addition of 6 per cent. sodium chloride, tryptic activity is delayed, and there is obvious curdling. Thus a regulating mechanism is provided, which delays the onward passage of the milk should pancreatic digestion be enfeebled, strongly suggesting that, as long as this is active, the formation of a curd has no particular advantage. At any rate, the frequency with which I have seen tough cheesy masses in the stomachs of infants post-mortem has impressed me with the accompanying drawbacks.

Calcium and the Clotting of Blood.—In the clotting

of blood, the part played by calcium is different. Fibrin ferment results from the interaction of three substances—thrombogen in the plasma; thrombokinase contained in all tissue cells, including the leucocytes and platelets; and calcium salts. Once the ferment has been formed, the calcium can be removed without interfering with the clotting. Thus it operates at an earlier stage than in curdling.

Wright has observed the rate of coagulation by means of a capillary tube, into which the blood is drawn, and the time required for clotting noted, hoping in this way to control the effect of therapeutic measures. If coagulation be too quick, the blood could be decalcified by giving citrate of soda; if too slow, calcium salts could be added.

Addis (*Quarterly Journal of Medicine*, vol. ii., p. 149) seriously questions the accuracy of Wright's method, and therefore of his deductions. While admitting the force of his criticisms, we must recognize that certain conditions are benefited by giving citrates, and others by calcium salts.

Indications for Decalcification.—Wright asserts that every adult patient who is put upon a diet of milk is thereby predisposed to thrombosis, in consequence of the large intake of calcium salts. He believes this accounts for the frequency of thrombosis as a sequel of typhoid fever. F. J. Smith also thinks that he greatly diminished the frequency of thrombosis in typhoid fever by allowing a more liberal and not exclusively milk diet.

Thrombosis occurred, with special frequency, as a sequel to typhoid fever in the South African War.* The usual explanation given was that prolonged marching had thrown a strain on the veins of the leg, but as thrombosis is such a late event in the disease, this must have lost its effect during the long enforced rest that preceded the clotting. It seems to me much more likely that the general use of condensed milk played an important part. Fresh milk contains some citric acid, thus providing the antidote to some of its abundant calcium. This citric acid is apt to separate out in an insoluble form from condensed milk.

Hæmatemesis from a gastric ulcer may be followed by thrombosis. Here, also, milk diet may play a part.

In all cases where milk diet is used for some time citrate of soda should be added. Such a simple procedure would justify itself if it saved one patient from the dangers, pain, and chances of lifelong inconvenience entailed by thrombosis. It is important to carry the treatment well into convalescence, as after a time decalcification is followed by an increase in the calcium salts of the blood. This probably depends upon the return of the calcium salts into solution, which had combined with citric acid, but were not excreted.

When once clotting has occurred in a vein, the

* About 6 per cent. of all cases developed thrombosis, or double the proportion of the cases which do so in this country. Crombie's oft-quoted figures in which 25 per cent. suffered from thrombosis are vitiated by the fact that many of his cases were those invalided home on account of this complication.

question arises whether it is better to give citrates with the view of aiding resolution, or calcium salts to assist in getting the clot as firm as possible and thus diminishing the risk of embolism. Practical experience is in favour of decalcification as soon as thrombosis takes place, for when clotting begins it may spread unless the coagulability of the blood is diminished. It has already been stated that fresh lemon-juice is believed by some to be more effective for this purpose than sodium citrate.

Indications for Increasing Coagulability.—Wright's attention was drawn to this subject because as a boy he was subject to severe giant urticaria when he took acid fruits, which are, of course, rich in decalcifying agents. Chilblains, 'angio-neurotic' œdema, and physiological albuminuria, he considers to be, like urticaria, due to lowered coagulability of the blood, which permits transudation of plasma from the vessels into the lymph spaces—a 'serous hæmorrhage,' as he calls it. Gewin found that serum sickness was much less common if calcium salts were given by the mouth at the time antitoxin was injected. The bearing of this on functional albuminuria has been referred to in Chapter VII. In all these conditions the blood must be replenished with those salts which render the plasma more coagulable and viscid.

For this purpose calcium lactate has yielded the best results. This salt has the following advantages: firstly, it is devoid of unpleasant taste, is sufficiently soluble (about 1 in 10) in water, and is suitable

for administration in the form of powders; and, secondly, as the salts of organic acids, and more particularly of lactic acid, are readily oxidized in the body, their bases are more readily utilized. A dose of 4 grammes (1 drachm) may increase the coagulability of the blood within twenty minutes, and maintain its effect for from four to seventeen days. It should be given when it is desired to exalt coagulability as rapidly as possible. When the object is to maintain a permanently high level of blood coagulability, the dosage should be 1 gramme (15 grains) three times a day.

Magnesium salts bring about a similar change, which explains the rationale of magnesium carbonate in the treatment of urticaria, and its special efficacy in that form of urticaria which follows upon the ingestion of decalcifying agents.

Calcium salts are used with the intention of promoting clotting in the sac of an aneurysm, in purpura, hæmophilia, intestinal hæmorrhage, and as a precautionary measure against bleeding during operations, but I have not been impressed with the results. Cushny doubts whether any improvement observed in such cases can really be referred to the drug, since much more calcium is taken in with the food than is sufficient for the body. On the other hand, Addis, though denying that the coagulation-time is increased, admits that the amount of ionizable calcium in the blood can be increased by the administration of soluble calcium salts.

G. W. Ross met with severe chronic headache,

troublesome urticaria, and deficient coagulability of the blood in a patient. Calcium chloride was given for the urticaria, and the headaches vanished also. This suggested to him that the headache might also be due to a similar 'serous hæmorrhage' into the meninges. He treated forty-eight cases with 15 grains of the chloride or the lactate of calcium three times a day. Forty of the cases obtained complete relief and eight considerable relief. With the relief, the coagulability of the blood was exalted in all the cases in which it was tested. According to him the type of headache which responds to this treatment presents the following characteristics:

1. It is present and most severe on waking, and tends to disappear one to six hours later.

2. It is usually a dull, heavy ache or a frontal or temporal throbbing; occipital, vertical, or unilateral pain being less common.

3. It is very chronic, often of several years' duration, and most intractable to ordinary treatment.

Women are more frequently affected than men. The expression is heavy and listless, the face is full, and the eyes are often puffy. Some anæmia is usual; constipation is the rule; loss of appetite and indigestion are common. There is a tendency to chilblains, urticaria, and œdema, the latter manifesting itself more commonly as a morning fulness between the eyes, and less frequently as an œdema of the ankles and feet. The patient sleeps heavily, but wakes without feeling rested, and there is a tendency to mental depression.

Irritability combined with languor he regards as characteristic.

He found the symptoms returned on decalcification of the blood by sodium citrate, to disappear a second time on treatment with calcium lactate.

Calcium and the Rhythm of the Heart.—In Chapter XI. it was shown that calcium salts were essential to the systole of the heart. Howell and Duke found that increase in the concentration of calcium salts acted like stimulation of the accelerator nerve. There was chiefly augmentation of the beat. A reduction in the calcium salts caused a more rapid as well as a more feeble beat. In the total absence of calcium the heart does not beat, though the electrocardiogram shows that the metabolic changes still continue.

Calcium has accordingly been used as a heart tonic in pneumonia; but it has not been an invariable success, and has sometimes been followed by thrombosis—not an uncommon accident in this disease. In acute infections 'heart failure' is often essentially a vasomotor paralysis; and calcium is a two-edged sword in the treatment of circulatory failure, because of its liability to provoke clotting.

Calcium Salts and Rickets.—Deficiency of lime in the food affects the young more than adults, since the former require more for the forming of the skeleton. Puppies fed on a diet poor in calcium pass into a state resembling rickets, owing to deficient growth of the bones. Pigeons thus dieted exhibit fragility and

atrophy of the bones. It might be expected, therefore, that calcium salts would benefit rickety children, but such is not the case. There is no lack of lime in the blood in rickets, but from some cause the power of taking it thence and depositing it in the bones is diminished. Lime starvation, therefore, merely causes an imitation of rickets, because the bone cells, though still ready to deposit calcium, cannot obtain it.

Calcium and the Puerperal State.—During pregnancy the blood has a brief coagulation-time, probably because it is rich in nutrient matters, including calcium salts, required for the growth of the fœtus. Winckel finds that it has a somewhat diminished alkalinity, which would enable it to hold a larger amount of calcium in solution.

Immediately after delivery blood clots rather more quickly than normal. As suckling begins, coagulation becomes perceptibly slower from the drainage of calcium salts into the milk. Hingston Fox suggests that observation of the coagulation-time of the blood after delivery might give timely warning of the risk of thrombosis or embolism if it were quick, or of post-partum hæmorrhage if it were slow. Appropriate treatment, with citric acid on the one hand, or with calcium lactate on the other, might help to rectify this.

Eclampsia has also been referred to a drainage of calcium salts from the mother to the fœtus, but probably on inadequate grounds.

The part played by ovarian activity in the metabolism of calcium is probably considerable, but is not

completely understood. The benefits sometimes seen after removal of the ovaries in osteomalacia may depend on this, for the calcium loss in the urine is then replaced by a marked retention. This improvement is sometimes only temporary, but is interesting in view of Blair Bell's observation of the abundance of calcium salts in pregnant women, where menstruation is naturally in abeyance.

It is clear that calcium excretion is decreased by thyroidectomy and increased by thyroid extract, but the significance of this is not known.

Many of the other therapeutical applications of calcium salts depend either on their physical state—as, for instance, the use of chalk as an astringent—or on their alkalinity, and do not, therefore, concern us here. The usefulness of a decalcifying agent in oxaluria has already been explained.

The Allied Metals, Barium and Strontium.—Barium is the most poisonous metal of the group. It is very slowly absorbed from the bowel, and may excite vomiting and purging, with very active peristalsis. It is incapable of replacing calcium in its relations to living matter, and is not nearly so efficient in maintaining the rhythm of the excised heart. According to some observers, it can replace calcium to a limited extent in the coagulation of the blood. It has been used principally for its effect on the cardio-vascular system. The waters of Llangammarch Wells owe their reputation in the treatment of heart disease largely to the barium they contain. Like digitalis, barium causes

the frog's heart to beat more slowly, but more strongly, and it produces a rise of blood-pressure by constriction of the bloodvessels. As the action is, apparently, directly upon the muscle fibres, I have used this drug in vasomotor paralysis, where it is useless to stimulate the exhausted or intoxicated nervous system further.

Strontium is the least poisonous of the three, being comparatively inert, even when injected directly into the blood. Like the others, it is absorbed very slowly from the bowel. It can replace calcium more or less perfectly in its influence on the heart-beat. It has been used chiefly for its anion, in the form of strontium bromide, for epilepsy; but, as it is absorbed so much more slowly than the corresponding salts of sodium or potassium, it is much less satisfactory for this purpose.

Antagonism of Calcium to Magnesium.—Although magnesium salts, like calcium salts, according to Wright, can exalt the coagulability of the blood in appropriate doses, these two metals are generally antagonistic in their effect on the tissues. Meltzer and Auer showed that the intracerebral instillation of two or three drops of a solution of magnesium sulphate produced a peculiar paralysis in rabbits, while injection of other salts was either indifferent or caused convulsions. The subcutaneous or intravenous injection of magnesium salts caused a general anæsthesia with paralysis, in which the reflexes were abolished and the blood-pressure was lowered. With a dangerously large dose, respiration ceased, the heart usually continuing to beat for some time longer. But as long

as there were some efficient heart-beats and a few respiratory gasps, the intravenous injection of a calcium salt, such as the chloride or the acetate, infallibly improved the respiration at once, and quickly revived the animal.

Magnesium favours inhibitory processes in the body, and in this it is definitely antagonized by calcium. This inhibitory action of magnesium suggested its use in the treatment of tetanus. It can have no action on the toxin, but by controlling the spasms it keeps up the patient's strength, and gives him time to form his own antitoxin. The results have been encouraging. Most of the recorded cases have been treated by subarachnoid injections, but Peter Paterson (*Lancet*, 1910, vol. i., p. 922), has reported a successful example of its subcutaneous use. At first 10 c.c. of a 10 per cent. sterilized solution of magnesium sulphate were injected every four hours for two days; later, 20 c.c. were similarly injected for four days. The great objection to the method is the pain produced by the injections, but probably this could be mitigated by using larger quantities of a more dilute solution.

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INDEX

Abdominal massage, 119
support, Curtis's, 125, 283
Acetone, 232
bodies in urine, 222
Acetonuria, 77, 226, 233
Achlorhydria, 60, 63
Achondroplasics, 8
Achylia gastrica, 55, 57
Acid intoxication, 232, 238
and pernicious vomiting of pregnancy, 254
and post-anæsthetic poisoning, 254
and recurrent vomiting of children, 253
treatment of, 249
Acidity, fresh fruit and, 168
potassium citrate in, 167
whey in, 169
Acid of gastric juice, 55
sodium phosphate, 179
Acidol, 64, 150
Acidosis, 232, 234, 238
in broncho-pneumonia, 245
in gastro-intestinal acetonuria, 245
in recurrent vomiting, 241
post-anæsthetic, 245
significance of, 232
symptoms associated with, 241
vomiting of pregnancy and, 242
Acids, time of administration, 64
Aconitine, 306
Acromegaly, 34
sexual power in, 35
spontaneous glycosuria of, 34
Addison's disease, 217, 343
adrenine and, 26
diagnosis of, 28
suprarenal extract and, 27
Adenin, 154
Adenomata, 29
Adherent pericardium, 361
Adolescent albuminuria, 187
Adrenal glycosuria, 216, 218
Adrenalin, 3, 15, 306, 332
borate, 17
chloride, 17
eye-test, Loewi's, 145, 216
Adrenine, Addison's disease and, 26
alkalies and, 25, 30
angina and, 19
ascites and, 23
asthma and, 21
by mouth, 28
cerebral hæmorrhage and, 22
chloretone and, 23
cocaine and, 25
contra-indicated, 31
dangers of, 29
diagnosis of Addison's disease and, 26
effect on eye, 31
on uterus, 24
eucaine and, 25
glaucoma, 24
hæmoptysis, 22
hay fever, 24
novocaine and, 25
pleural effusion and, 23
pneumonia and, 20
purpura and, 22

Adrenine, respiratory system, 21
shock, 20
spinal anæsthesia, 26
stovaine, 25
surgical applications, 23
Albuminuria, 177, 187
adolescent, 187
alimentary, 187
blood-pressure and, 342
cyclic, 187
functional, 187
glycosuria and, 224
life insurance and, 192
organic, 193
orthostatic, 190
physiological, 375
postural, 187
pregnancy and, 9
public services and, 192
Albumosuria, 182
Alcohol, 164, 237
Alcoholism, 145, 302
Alimentary albuminuria, 187
canal, adrenine in, 17
glycosuria, 221, 224
Alkalies, adrenine and, 25, 30
time of administration, 63
Alkaline urine, 251
Alkalinity, titration, 238
Alkaptonuria, 161, 211
Almond-oil in dyspepsia, 68
Aloes, tincture of, 113
Alypin, adrenine and, 25
Amino-purins, 154
Ammonio - magnesium phosphate, 180
Ammonium bromide in dyspepsia, 68
sulphocyanide, 90
Amyl nitrite, 329, 332, 350
manometer and, 350
Amylopsin, 135, 144, 146
Anæmic necrosis, 305
Anæsthesia, local, adrenine in, 24
traditional demands of, 247
Aneurism, 337, 376
Angina, 310
adrenine and, 19
Angio-neurotic œdema, 375
Animal extracts, 2
Antacidol, 68
Antidromic impulses, 322
Antifebrin, 211
Antigens, 4
Antipyrin, 211
Antithyroidin, 13
Antitrypsin, 133
Aortic regurgitation, 334
Apoplexy, 330
lumbar puncture in, 331
venesection in, 330
Appendicectomy, 127
Appendicostomy, 284
Appendix dyspepsia, 96
Appetite, value of, 44
Arginine, 261
Argyrism, 68
Arterial tension, high, insomnia in, 325
Arterio-sclerosis, 343
classification of, 347
hyperpietic, 347
involutionary, 374
manometer in, 343
secondary, 374
toxic, 347
Ascites, adrenine and, 23
Asparagus, 155, 174
Asphyxia, 319
glycosuria in, 219
Aspirin, 152, 231
Asthenic dyspepsia, principles of treatment in, 63
Asthma, adrenine and, 21
Atheroma, 305
Athletic heart, 314
overwork of, 316
Athyrea, 11
Atonic dilatation, 99
dyspepsia, 61
treatment of, 66
Atophan, 166
Atropin, 308
Auricular fibrillation, 311
flutter, 302
Auriculo - ventricular bundle, 287, 318
knoten, 288
node, 288
Autolysis, 239

Bacillus aerogenes capsulatus, 267
aminophilus, 242
coli, 242, 260, 266, 284

Bacillus coli communis, 268
nitrifying, 274
Oppler-Boas, 89
putrificus, 260, 266
Bacteria, limitation of, 280
Baldwin's oxalate-free diet, 174
Barium, 380
Beat of the heart, 336
Beef-tea, value of, 367
Beetroot, 174
Belladonna in dyspepsia, 68
Beri-beri, 366
vitamines in, 367
Betain chloride, 64, 150
β-naphthol, 281
β-oxybutyric acid, 233
Bicarbonate of sodium, 251
Bilious attacks, 254, 266
Biliousness, 242
Biochemical apparatus, 4
Bismuth, in X rays, 48
liq. bismuthi hydratis, 67
lozenge, 67
Bladder, pituitrin and, 33
Blood, calcium and clotting of, 372
Blood-pressure, 335
albuminuria and, 342
beat of heart, 336
elasticity of vessel wall, 337
in later life, 347
methods of estimating, 339
peripheral resistance and, 336
tobacco and, 345
volume of circulating blood, 337
Blood-pressure, high: diet in, 348
treatment of, 348
Blood vessels, adrenine and, 19
Body temperature, pituitrin and, 32
Brain, blood-supply of, 327
extract, 2
Branchial clefts, 39
Bright's disease, 193, 204
diuretics in, 204
Bronchial glands extract, 2
Broncho-pneumonia, acidosis in, 245
Brusson-Jeune rolls, 228
Bulgarian bacillus (milk), 89
Butyric intestinal putrefaction, 267

Cadaverin, 185
Caffein, 154, 158, 204, 306, 308
Calcium, antagonism to magnesium of, 381
chloride, 377
clotting of blood and, 372
curdling of milk, 369
excretion of, 369
intake, 184
lactate, 375
in functional albuminuria, 191
oxalate, 172
phosphate, 180
puerperal state and, 379
rhythm of heart and, 378
rôle of, 368
salts, 365
rickets and, 378
trypsinogen and, 133
Calculi, composition of, 172
oxalate, 177
Calculus cystin, 185
Calomel, 280
Cammidge's pancreatic reaction, 135, 148
Camphor, 210
Cancer, thyroid in, 9
Capsules of gelatin, 151
keratin-coated, 151
Carboluria, 264
Carboxyhæmoglobin, 352
Carcinoma, gastric, 89
of intestines, 123
Cardiac compensation, 317
rhythm, 286
auricular fibrillation, 296
disturbed, types of, 294
treatment of, 311
extra-systoles, 299
heart-block, 303
pulsus alternans, 308
sinus irregularity, 294
Cardiac muscle, physiological peculiarities, 291
Cardio-sclerosis, 310
Carotid body, 15
Caseinogen, 149

Catarrhal jaundice, 142
Cell-islets, meaning of, 139
Cerebellar hæmorrhage, 219
Cerebral anæmia, 324
hæmorrhage, adrenine and, 22, 31
treatment of, 329
Cheese, 279
Chemical factor in gastric digestion, 45
Cheyne-Stokes respiration, 310
Chilblains, 375
Children and fat-eating, 51
operations on, 254
recurrent vomiting of, 253
Chittenden's diet, 196, 201
experiments, 196
Chloral, 210
Chloretone, adrenine and, 23
Chlorides, estimation of, 90
Chloroform, 210
-poisoning, adrenine and, 20
Cholalic acid, 186
Cholecystitis, 268
Cholecystostomy, 152
Chyluria, filarial, 74
Circulation, placental, 359
Cirrhosis of the liver, 277
Citrate of potassium, 167, 206, 251
of sodium, 370, 375
Citrated milk, 370
Citric acid, 237
Clotting of blood, calcium and, 372
Coagulability, indications for diminishing, 373
increasing, 375
Cocaine, adrenine and, 25
Codein, 231
Cœcal fistula, 116
Coffin-lid crystals, 180
Colchicine, 167
Colchicum in gout, 167
Collapse, adrenine and, 20
Colon, congenital idiopathic dilatation of, 118
excision of, 284
irrigation of, 284
removal of, 119
short-circuiting of, 284
Coma, diabetic, 241
Compensation, cardiac, 317
Compression, symptoms of, 329
Condensed milk, thrombosis and, 374
Congenital hypertrophic stenosis of the pylorus, 107
Contrexéville water, 168
Coronary vessels, adrenine and, 19
Corpora lutea, destruction of, 36
Corpora quadrigemina, 320
Cow's milk curd, 369
Cretinism, 7
Curdling of milk, 372
calcium and, 369
Curds, undigested, 372
Curtis's abdominal support, 125, 283
Cutaneous tissues, pituitrin and, 32
Cyanosis, 352
chronic, 361
congenital heart disease in, 358
local, 363
microbic, 272
toxic, 353, 363
traumatic, 363
true, 353
Cyclic albuminuria, 187
Cyllin medical, 281
Cystin, 184, 262
calculus, 185
Cystinuria, 161, 184
Cystitis, 181, 268
Cytolytic sera, 14

Decalcification, indications for, 373
Defæcation, 117
Defective teeth, 92
Depressor branch of the vagus, 323
Diabetes, 136, 210
acidosis and, 241
aspirin and, 231
codein and, 231
insipidus, diagnosis of, 33
pituitrin and, 33
salicylate and, 231
Diabetic coma, 219, 241

Diabetic coma, alkalies in, 252
diet, 229
standard, 226
fruit-sugar for, 228
oatmeal for, 228, 367
potatoes for, 228
Diacetic acid, 232, 240
tests for, 219, 233
Diaphoresis in nephritis, 208
Diastase, increase in urinary, 146
Diastolic pressure, 339
Diet, Baldwin's oxalate-free, 174
Chittenden's, 196
diabetic, 229
Folin's, 199
Von Noorden's standard, 226
Dietetic restrictions, 51
Digestion, effect of starch on, 65
mechanical factors in, 92
Digitalis, 204, 205, 306, 308, 311, 316
action of, 298
reaction to, 313
toxic action of, 298
Dilatation, pyloric spasm and, 110
of stomach, 101
Dilated heart, 318
Distoxication, Guelpa's method, 283
Diuresis, methods of producing, 204
Diuretics, 204
Bright's disease and, 204
Diuretin, 205, 316
Douches, Plombières', 283, 349
Ductus arteriosus, 359
Duodenal ulcer, 56, 86, 123
Duodenum, discharge of food into, 111
Dyschezia, 118
Dyspepsia, 43
appendix, 96
atonic, treatment of, 66
reflex, 59
treatment of, 67
Dyspnœa, non-cyanotic, 352

Eck's fistula, 259
Eclampsia, 379
puerperal, 254
thyroid in, 9
Einthoven's string galvanometer, 285, 297
Emotion and diarrhœa, 113
Emphysema, 362
Enema, nutrient, 75
Enemata, 116
Enterokinase, 132
Epidemic dropsy, 366
Epistaxis, 344
Erepsin, 71, 136, 159
Ergot and pituitrin, 36
Erythræmia, 354
Erythrol tetranitrate, 312, 350
Erythromelalgia, 325
Eserine salicylate, 113
Ethyl butyrate, 135
Eucaine and adrenine, 25
Excision of colon, 284
Exophthalmic goitre, 145, 302
pituitrin and, 35
Extracts, animal, 2
of kidney, 42
Extrasystole, 294, 299, 311
Eye, adrenine and, 31
pituitrin and, 33
Eye-test, Loewi's adrenalin, 145, 216

Fæces, alkaline, 282
examination of, for occult blood, 61
Fainting, change of posture and, 324
tapping ascites and, 324
Fat digestion, failure of, 144
necrosis, 134
Fatty infiltration, 305
liver, 249
Fear, expression of, 12
Fehling's solution, 210
Fibrin ferment, 373
Fibrosis, 305
Filarial chyluria, 74
Fistula, Eck's, 259
Flutter, auricular, 302
Folin's diet, 199
Fractures, thyroid extract in, 9
Fröhlich's syndrome, 34, 218
Fruit-sugar for diabetics, 228
Functional albuminuria, 187
calcium lactate in, 191
treatment of, 193

Gall-stones, 268
Galvanometer, Einthoven's string, 285, 297
Gastric carcinoma, 55, 89
contents, examination for, 87
digestion, chemical factor in, 45
nervous factor in, 43
vagus and, 44
disorders, rational treatment of, 43
juice, acid of, 55
mill, 50
secretion, 2, 3
sepsis, 276
ulcer, 86, 98
immediate feeding in, 80
treatment of, 69
Gastro-enterostomy, 103, 104
for pyloric spasm, 110
Gastro-intestinal acetonuria, acidosis in, 245
intoxication, 257
Gastro-jejunostomy, 85, 100, 127
Gastroptosis, 96, 101
Gastrostaxis, 70
Gastrostomy, feeding after, 55
General metabolism, pancreas and, 136
Glaucoma, adrenine in, 24
Glidine, 229, 230
Glutaric acid, 237
Gluten foods, 228
Glycerine as mouth-wash, 79
Glycosuria, 137, 150, 210, 219
adrenal, 216, 218
albuminuria and, 224
alimentary, 145, 221, 224
asphyxial, 219
concussion and, 218
intermittent, 222
iodothyrin and, 8
physiological, 214
pituitary, 217
post-anæsthetic, 220
pregnancy and, 221
puncture, 218
renal, 215
thyroid, 217
treatment of, 225
Glycosuria, tuberculous meningitis and, 220
Glycuronic acid, 210
Goose-gait, 212
Gout, alcohol in, 164
atophan in, 166
colchicum in, 167
diet in, 163
drugs in, 164
lithium salts in, 164
piperazin in, 164
purins and, 161
salicylates in, 165
urotropin in, 164
Gravel, 167
Graves' disease, 11, 40
diet in, 14
disease, organo-therapy in, 12
sugar tolerance in, 217
thymus in, 39
thyroid in, 39
Growth and pituitrin, 32
Grünbaum's method, bile-salts, 9
Guanin, 154
Guelpa's method of distoxication, 283
Gunzberg's test for free HCl, 89

Hæmatemesis, 17
in young females, 70
treatment for, 70
Hæmatoporphyrinuria, 275
Hæmaturia, 176, 177, 178, 344
Hæmophilia, 376
adrenine in, 22
Hæmoptysis, adrenine in, 22, 31
of phthisis, 332
Hæmorrhage, intestinal, 18, 376
or thrombosis, diagnosis, 341
Hassall's corpuscles, 39
Hay fever, adrenine and, 24
Headaches on waking, 377
Heart, 334
adrenine and, 19
athletic, 314
beat of, 336
-block, 294, 303
calcium and rhythm of, 378
dilated, 318
disease, congenital, cyanosis in, 358

Heart failure in acute infections, 340
hypertrophied, 318
irregular action of, 285
muscle, powdered, 2
overwork of athletic, 316
pacemaker of, 294
pituitrin and, 33
vasomotor system and, 334
Helmitol, 152
Hemianopsia in acromegaly, 34
Herter's infantilism, 131
Hiccough, adrenalin in, 18
High blood-pressure, treatment of, 348
Hirschsprung's disease, 118
Histidene, 242
Holadin, 151
Homogentisic acid, 211
Hormones, 3, 36
employment of, 5
general features of, 5
Horse-serum, 86
Hour-glass contractions, spasmodic, 95
stomach, functional, 96
true, 97
Hunger-pain, 56
Hydroa æstivalis, 276
Hydrochloric acid, examination for, 87
Gunzberg's test for, 89
of gastric juice, 55
Hydrogen peroxide, 281
in lavage, 101
Hyperchlorhydria, 56, 59, 60, 67, 151, 180, 183
appetite for indigestible things and, 57
meat soups and, 53
pain and, 56
pyloric spasm and, 56
pyrosis and, 57
Hyperglycæmia, 34, 214
Hyperthyrea, 11
Hypertrophic stenosis of the pylorus, congenital, 107
Hypertrophied heart, 318
Hypophysis cerebri, 31
Hypopituitarism, 32
amenorrhœa and, 32
impotence and, 32
Hypopituitarism, primary, 218
Hypoxanthin, 154, 158, 159

Iceland moss, 125
Ichthyol, 281
Ichthyosis, 9
Impotence, treatment of, 39
Indican, 211, 262
tests for, 262
Indicanuria, 263
Indigestion, mechanical factors in, 92
Indol, 262, 263
Indolic and butyric intestinal putrefaction combined, 267
intestinal putrefaction, 266
Indoxyl-sulphate of potash, 262
Infantilism, 131
Herter's, 131
persistent, 130
Influenza, 305
Insomnia, 324, 325
cold feet and, 324
Insurance companies' rules, 192
Intermittent glycosuria, 222
Intestinal antisepsis, 280
hæmorrhage, 18, 376
pituitrin in, 35
intoxications, 256
avoidance of putrefactive contamination of food, 279
Guelpa's method of distoxication, 283
limitation of number of bacteria, 280
mechanical supports, 283
Plombières' douches, 283
promotion of prompt digestion and absorption, 279
specific, 268
surgical procedures, 284
treatment of, 279
vaccine treatment of, 284
paresis, pituitrin in, 35
putrefaction, chronic, 266
sepsis, 276

Intestinal short circuits, 127
stasis, consequences of, 119
symptoms of, 122
women and, 126
Intestines, 111
large, movements of, 115
small, movements of, 112
Intoxication, acid, 238
Intoxications, intermediate products of digestion and, 258
intestinal, 256
products of putrefaction and, 260
Intracranial pressure, 327, 331
Iodine, 7
Iodothyrin, 3, 5, 6, 7, 8
diuretic action of, 10
dose of, 10
glycosuria from, 8
Ionized salts, cardiac action and, 292
Irregular action of the heart, 285
Irrigation of colon, 284
Izal, 281

Jaundice, catarrhal, 142
thyroid extract in, 8
Joints, chronic affections of, 277

Keratin-coated capsules, 151
Kidney, 41
extracts of, 42
pituitrin and, 33
Knife-rest crystals, 180
Kreatin, 3
Kreatinin, 210

Lactate, calcium, 375
Lactic acid ferments, 281
Lactose, 212
Lactosuria, alimentary, 212
Lævulose, 212, 228
Lævulosuria, alimentary, 212
Laparotomy, 134
Large intestines, movements of, 115
Lavage of stomach, 101
Lead-poisoning, peristalsis in, 114
Lecithin, 38
Lemon-juice, 179, 375
Leucin, 235, 261
Levator ani in constipation, 118
Life insurance, albuminuria and, 192
Limbic bands of the auricle, 358
Limitation of bacteria, 280
Liquor pancreaticus, rectal feeding and, 71
Lithium salts, 164
Liver, 155
cirrhosis of, 277
fatty, 249
Llangammarch Wells, 380
Local cyanosis, 363
Loewi's adrenalin eye-test, 145, 216
Louping-ill, 269
Lumbar puncture, 331
Lungs, vasomotor system in, 332
Lupus vulgaris, 9
Lymphatism, 40

Mackenzie's polygraph, 285
Magnesium, antagonism of calcium to, 381
phosphate, 180
salts, 376
tetanus and, 382
Malignant disease in alimentary tract, diagnosis of, 61
Mammary secretion, pituitrin and, 33
Mannitol, 350
nitrate, 312
Manometer, 339
amyl nitrate and, 350
Massage, abdominal, 119
Mayo clinic, 135
Meat, 174
bolting of, 92
extracts, value of, 53
juice, 42
lightly cooked, minced, 54
minced, 102
Meat soups, hyperchlorhydria and, 53
Mechanical factors in digestion, 92
in indigestion, 92
supports, 283
Menthol, 281
Metallic salts, 365

Methæmoglobin, 272
Methæmoglobinæmia, 352, 353
Methods of estimating blood-pressure, 339
Methyl-purins, 154
Microbic cyanosis, 272
Middle sphincter, stomach, 95
Milk, 155, 174
  calcium and curdling of, 369
  citrated, 109, 370
  curdling of, 372
  diet, danger of, 374
Mongolian idiots, 8
Morphia, 210, 316
Mouth-wash, glycerine as, 79
Movements of small intestines, 112
  of stomach, 47
Mucous colitis, 123
Mulberry-stones, 177
Myxœdema, 7, 11, 217

Naphthalene tetrachloride, 281
Nauheim baths, artificial, 349
Necrosis, fat, 134
Nephritis, acute, diet in, 203
  tension in, 342
  chronic, conventional treatment of, 194
  diaphoresis in, 208
  salt in, 202
  scarlatinal, 203
  treatment of, 187
Nerves, afferent, 322
  constrictor, 321
  depressor, 323
  dilator, 321
  efferent, 321
  pressor, 322
Nervous factor in gastric digestion, 43
  mechanism, 4
Neurasthenia, 181
Nitrite-producing microbes, 353
Nitrites, over-employment of, 350
Nitrogen, Kjeldahl's method, 200
Nitro-glycerine, 205, 350
Nose, adrenine and disease of, 24
Novocaine, adrenine and, 25
Nutrient enemata, 75, 80

Oatmeal, 155
  diabetes and, 367
Obermayer's test for indican, 262
Obesity, iodothyrin in, 8
Occult blood, 61
  test for, 62
Ochronosis, 212
Œdema, angio-neurotic, 375
  of the lungs, 333
  venesection in, 334
Œsophagus, malignant stricture of, 94
Oligocythæmia, 363
Olive-oil in dyspepsia, 68
Operations on children, 254
Opium-poisoning, adrenine in, 20
Oppler-Boas bacillus, 89
Oral sepsis, 276
Organic albuminuria, 193
Organo-therapy, principles of, 1
  rational, 1
Orthostatic albuminuria, 190
  "hour-glass" stomach, 97
Osteomalacia, 380
Ovarian extract after climacteric, 37
  after ovariotomy, 37
Ovary, 36
Overwork of the athletic heart, 316
Oxalate calculi, 177
Oxalates, 174
Oxalate-free diet, Baldwin's, 174
Oxalic acid, 176
Oxaluria, 171, 173, 175, 177
  treatment of, 178
Oxidases, 357
Oxybutyric acid, 240
Oxygen starvation, 236
Oxy-purins, 154

Pacemaker of the heart, 294
Pachon's apparatus (blood-pressure), 339
Pancreas, excision of, 215
  general metabolism and, 136
  work of, 128
Pancreatic disease, diet in, 149
  manifestations of, 142
  pressure symptoms in, 148

Pancreatic disease, treatment in, 149
Pancreatic disintegration, signs of, 146
ducts, disinfection of, 152
ferments, 135
fistula, 130
hæmorrhage, 133
inadequacy in infants, 109
signs of, 143
juice, 3, 372
secretion of, 128
reaction, Cammidge's, 135, 148
secretion, 2
regulation of, 150
tests, 149
Pancreatitis, chronic, 144, 151, 175
Pankreon, 151
Pappy foods, Harry Campbell on, 54
Paraffin, liquid, 124
Paraganglia, sympathetic, 15
Paragangline, 15, 29
Paralytic chorea in sheep, 269
Parathyroids, Forsyth on, 11
tetany after excision of, 10
Paroxysmal tachycardia, 302
Pellagra, 366
Pelvic shelf, rectification of, 127
Pentose, 212
Pentosuria, 161
Pepsin, 55
Perforation in typhoid, 342
Pericardium, adherent, 361
Perigastric adhesions, 97
Peristalsis, adrenalin and, 17
general law of, 50
Pernicious anæmia, 276
vomiting of pregnancy, acid intoxication in, 254
Persistent thymus, 40
Petroleum, 281
Phenolphthaleïn, 89
Phenylchinolin, 166
Phlebitis, 178, 268
lemon-juice in, 179
Phloridzin-poisoning, 215
Phloroglucin, 89
Phosphates in urine, 179
Phosphaturia, 171, 179
Phosphaturia, treatment of, 183
Phosphoric acid, 184
Phthisis, hæmoptysis of, 332
Physiological reserve, 4
Physostigmin, 306
Pigmentation in Addison's disease, 27
Piperazin, 164
Pituitary body, 31
diabetes insipidus and, 33
glycosuria and, 217
polyuria and, 33
pregnancy and, 35
Pituitrin, 3, 29, 31, 32
bladder and, 33
body temperature and, 32
cutaneous tissues and, 32
ergot and, 36
exophthalmic goitre and, 35
eye and, 33
growth and, 32
heart and, 33
intestinal hæmorrhage and, 35
intestinal paresis and, 35
kidney and, 33
mammary and, 33
pregnancy and, 33
sexual organs and, 32
shock and, 35
Placental circulation, 359
Plasmon, 150, 230
Pleural effusion, adrenalin and, 23
Plombières' douches, 283, 349
Pneumonia, adrenalin and, 20
blood-pressure in, 342
uric acid in, 156
Poisoning, adrenalin in, 18
Polycythæmia, 363
absolute, 364
at high altitudes, 353
relative, 364
splenomegalic, 354
Polygraph, Mackenzie's, 285
Polyuria, pituitrin and, 33
Post-anæsthetic acidosis, 245
glycosuria, 220
poisoning, 254
Post-operative shock, 341

Postural albuminuria, 187
Potash-water, 168
Potassium citrate, 167, 178, 179, 206, 251
iodide, 349
permanganate in lavage, 101
Pregnancy, albuminuria of, 9
glycosuria of, 221
pernicious vomiting of, 254
pituitary body in, 35
pituitrin in, 33
Prescriptions, 252, 283
Principles of treatment in asthenic dyspepsia, 63
in reflex dyspepsia, 67
Protein intake, severe restriction of, 194
Voit standard of, 196
Protene, 150
Psoriasis, 9
Ptyalin, 144
Puerperal eclampsia, 254
state, calcium and, 379
Pulmonary tuberculosis, 302
Pulsus alternans, 294, 308
Puncture glycosuria, 218
Purgatives, action of, 116
Purin bodies, 153
ingestion of, 157
Purin-free diet, 52, 161
Purinometer, 170
Purins, 154, 155
Purpura, 376
adrenine in, 22
Putrescin, 185
Pyelonephritis, 268
Pyloroplasty for pyloric spasm, 110
Pylorus, congenital hypertrophic stenosis of, 107
Pyorrhœa, 100, 272, 278, 371
Pyramidon, 211
Pyrocatechin, 15
Pyrosis, 57

Quadriurate of soda, 164

Raynaud's disease, 325, 363
Reaction, Cammidge's pancreatic, 135, 148
Rectal feeding, 70
absorption of carbohydrates, 73
of fat, 74
of proteins, 72
of salt, 75
of water, 75
eggs in, 74
experiments in, 72
formula for, 75
nitrogenous metabolism during, 75
practical deductions, 78
vomiting in, 79
salines, 84
Recurrent vomiting of children, 241, 253
Reflex dyspepsia, 59
principles of treatment in, 67
Renal capacity, 198
glycosuria, 215
Rennin, 108
Respiratory system, adrenine in, 21
Rheumatism, acute, 305
Rheumatoid arthritis, 278
Rickets, calcium salts and, 378
Ringer's fluid, 293
Rodagen, 13

Sahli's method (capsules), 143
Salicylates in diabetes, 231
in gout, 165
Salivary secretion, 2
Salol, 281
Salt, nephritis and, 202
Salvator water, 206
Sarcinæ, 89
Scurvy, 366, 367
Secretin, 3, 129, 138
Senna, 116
Senoran's bottle, 88
Serous membranes, adrenine and, 23
Sexual development, premature, 29
organs, pituitrin and, 32
power in acromegaly, 35
Sham feeding, 43
Shock, adrenine and, 20
pituitrin and, 35

Short-circuiting of colon, 284
Silver nitrate in dyspepsia, 90
Sino-auricular node, 289
Sinus irregularity, 294, 311
Sinusoids, 139
Skatol, 262
Skin, thyroid extract in disease of, 9
Small intestine, movements of, 112
Soda, quadriurate of, 164
Sodii nitrit. co. tabloid, 351
Sodium bicarbonate, 251
in lavage, 101
chloride, 365
citrate, 179
nitro-prusside, 233
salicylate, 308
Soetbeer's treatment for phosphaturia, 184
Solurol, 165
Spasmodic hour-glass contraction, 95
Specific intestinal intoxications, 268
Spermin, 38
Sphygmometer, 338
Spinal anæsthesia, adrenine and, 26
Splash, succussion, 100
Splenomegalic polycythæmia, 354
Squills, 306
Staircase, cardiac, 291
Starch digestion, failure of, 144
effect on digestion, 65
Starvation, acidosis from, 235
element of, 235
Status lymphaticus, 40
Steapsin, 134
Stenosis of pylorus, congenital hypertrophic, 107, 371
Stercobilin, 148
Sthenic dyspepsia, 60
Stokes-Adams disease, 303
Stomach, 95
acute dilatation of, 101
atonic dilatation of, 99
dilatation of, 99, 101
lavage of, 101
movements of, 47
obstructive dilatation of, 102
Stomach, true hour-glass, 97
ulceration in, 61
X-ray photographs of, 48
Stovaine, adrenine and, 25
Strawberries, 174, 176
with lemon-squash, 179
Streptococcus fæcalis, 269
salivarius, 269
Strontium, 380
bromide, 381
Strophanthin, 314
Strophanthus, 205, 306, 312, 314
Strychnine, 119, 306, 308, 316
Substitution therapy, 5
Succi, case of, 73
Succus entericus, 132, 150
Succussion splash, 100
Sugar tolerance diminished, 145
Sulphæmoglobinæmia, 272, 353
Sulphonal poisoning, 275
Suprarenal extract in Addison's disease, 27
cortex, 29
Suprarenals, 14
Swallowing, act of, 92
Syncope, 319
Syphilis, congenital, 131

Tachycardia, paroxysmal, 302
Taka-diastase, 151
Tartaric acid, 237
Taurin, 186
Teeth, defective, 92
Testicular extract, 38
Test, Gunsberg's (HCl), 89
indican, 262
Loewi's eye, 216
meal, 61, 87
technique of, 87
Obermayer's (indican), 262
occult blood, 62
Willcox (HCl), 89
Testis, 37
Tetanus, magnesium in, 382
treatment of, 382
Tetany, 278
after excision of thyroids, 10
Tetronal poisoning, 275
Thein, 154
Theobromine, 154, 205, 308
Theocin-sodium acetate, 206
Thirst, relief of, 84

Thoracic duct, fistula of, 74
Thrombogen, 373
Thrombokinase, 373
Thrombosis, condensed milk and, 374
typhoid fever and, 373, 374
Thrombosis or hæmorrhage, cerebral (diagnosis), 341
Thymic asthma, 40
Thyminic acid, 164
Thymol, 281
Thymus, Graves' disease and, 39
persistent, 40
Thyroidectin, 13
Thyroid extract, 2
gland, 6
glycosuria, 217
Thyroidism, 7
in sucklings, 10
Thyrolytic serum, 13
Tight-lacing, 120
Titration alkalinity, 238
Tobacco, blood-pressure and, 345
tolerance of, 345
Toffee in acute nephritis, 203
Toxic effects of adrenine, 30
Traumatic cyanosis, 363
Tricuspid valve, diseases of, 361
Trional poisoning, 275
Triple phosphate, 180
Tripod of life, 325
Trypsin, 132, 133, 136, 372
Trypsinogen, 132
Tryptic digestion, failure of, 143
Tryptophan, 261, 266
Tuberculous meningitis, glycosuria of, 220
Typhoid fever, bleeding in, 18
citrates in, 372
perforation in, 342
thrombosis in, 374
Tyrosin, 261

Ulceration of stomach, 61
Urea estimations, 198
Uric acid, 153, 154, 158, 210
in urine, 167
Urinary calculi, 171
basis of, 171
irritation, 176
Urinary oxalates, sources of, 174
Urine, alkaline, 251
Urine, uric acid in, 167
Urochrome, 171
Urotropin, 164
Uterus, adrenine and, 24

Vanillin, 89
Vasomotor centre, 320
effect in lungs, absence of, 332
hemiplegia and, 341
paralysis, 341
abdominal binder in, 341
adrenalin in, 341
barium salts in, 341
brandy in, 341
digitalis in, 341
ergot in, 341
ether in, 341
pituitrin in, 341
strychnine in, 341
system in disease, 341
Venesection, 329, 330
in œdema of the lungs, 334
Visceroptosis, 119, 120, 283
results of, 120
treatment of, 124
Vitamines, 365, 367
Voit standard of protein intake, 196
Vomiting, adrenalin and, 18
Von Noorden's standard diet, 226

Wassermann's reaction, 308
Whey in acidity, 169
Wholemeal bread controversy, 367
Willcox's method for HCl, 89

Xanthin, 154, 159
X rays, 61

Yahourth, 282
Yeast, 89
Yoghourt, 282

Zomo-therapy, 42

LIST OF AUTHORITIES

(*Principal bibliographical references in thick type, as* **383**)

Abelmann, 142, 144
Abrahams, 4
Addis, 373, 376, **390**
Addison, 14
Adler, 155
Allanson, 45
Allbutt, Sir Clifford, 102, 314, 347, **389**
Anderson, McCall, 276
Aschoff, 305, **388**
Auer, 381, **391**

Bainbridge, 42, 237, **387**
Baldwin, 175
Baldwin, Dr. Helen, 243, **387**
Barger, 265, 346
Barnes, Robert, 118
Barr, Sir James, 23, 305
Baum, 21
Bayliss, 112, 129, 322, **385**
Beach, 363
Beattie, **387**
Beddard, 42, 239, 255, **387**
Bell, Blair, 33, 380, **390**
Berg, 104
Bergh, Van der, 272, 273
Bernard, Claude, 218
Bickel, 45
Blochmann, 119
Bolton, 105
Boycott, 356
Boyd, 72, 73
Bradford, Rose, 41, 216, **387**
Bramwell, Byrom, 9, 130, **385**
Broadbent, Walter, 68, **384**
Brodie, 21, **389**
Brown, Langdon, **384, 386**
Brown-Séquard, 14, 38
Bryant, 202
Bulloch, 29
Bunge, 63
Butler, 20
Bywaters, 80, **384**

Caldwell, 367
Cameron, H. C., **384**
Cammidge, 135, **385, 387**
Campbell, Harry, 54
Cannon, W. B., 49, 50, 65, 106, 111, 112, 113, 114, 123, **384**
Carlson, 293, **388**
Carmichael, **387**
Casper, 245
Cathcart, 130, 244
Celsus, 1
Chittenden, **386**
Church, 72
Clark, Sir Andrew, 52
Clarke, Wood, 274, 276, **388**
Clayton-Greene, 130
Cohnheim, 333
Collier, 189
Cooper, 305, **389**
Copeman, 58
Corbett, 148
Cowan, **388**
Crile, 20, 341
Crocker, Radcliffe, 9
Curtis, 283
Cushing, 35, 328, 331, **383, 390**
Cushny, 24, 313, 376

Da Costa, 303
Dakin, 15
Dale, H. H., 24, 140, 141, 265, 346, **385**
Darier, 23
Delezenne, 133

Dick, **386**
Dixon, 21, 167, 345, **389, 390**
Dudgeon, 23, **384**
Duke, 378
Dukes, 188, 191, **386**
Duncannon, 24
Dunlop, 175

Edel, 190
Edkins, 46, 109
Edmunds, 13
Edsall, 74
Ehrlich, 4
Elliott, 16, 17, 20, 112, **383**
Erlanger, 290, **389**
Ernberg, 203
Esbach, 176
Evans, 138
Exner, 18

Falconer, **388**
Fawcett, 164
Fenner, 165
Fischer, 153
Flack, 289, **389**
Flexner, 135
Forster, 365, 366
Forsyth, 11, **383**
Fox, Hingston, 191, 379
Foxwell, Professor, 200
Fraenkel, 36
Fraser, 141
Frew, 220, 246, **387**
Frölich, 367
Fromm, 258
Funk, 366, 367

Galen, 1, 70
Garratt, 157
Garrod, Sir Alfred, 162, 185, 213, 215, 217, 220, 245, 264, **386, 387, 388**
Gaskell, 286, 336, **389, 390**
Gee, 169, 177, 241, 242
Geelmuyden, 235
Gewin, 375
Gibson, 273, 312, 342
Gibson, A. G., 305, **389**
Gibson, G. A., 305, **388**
Gilbert, 8, 9
Goetsch, **383**
Goodall, 39, **384**
Goodbody, 91
Goodhart, 163, 168
Gordon, 164
Gordon, Dr., 267
Gore, 157
Graeser, 18
Graham, 58, 157
Griffin, Dr. F. W. W., 203
Grünbaum, 17, 27, 28
Guelpa, 283, **388**
Guleke, 134
Gulland, 328
Gumprecht, 339
Guthrie, 247, 254, **387**
Guthrie, Leonard, 245

Habermann, **384**
Haig, 153
Hake, 58
Hall, Walker, 154, 157, 162, 166, **386**
Halpern, 236
Hamilton, 269, 270, 277, **388**
Handford, 305, **389**
Harley, 91
Hart, Stuart, **387**
Harvey, 345
Hay, **389**
Henderson, 39, **384**
Hédon, 142
Hering, 290, **389**
Herscher, 8, 9
Herter, 131, 263, 266, 267, **388**
Hertz, A. F., 48, 56, 94, 96, 99, 106, 107, 113, 114, 116, 117, 118, 119, 125, **384, 385**
Hill, Leonard, 340, **390**
His, 287
Holst, 366
Hopkins, F. G., 27, 161, **391**
Horder, 271
Hort, 86
Howell, 378, **391**
Hunter, 276
Hurtley, 233, 237, 276, **388**
Hutchison, 198, 367

Janeway, 337, 339, 340, **390**
Jellasse, 96
Jellick, 305, **389**
Jerome, Smith, 168
Jolly, 36
Jordan, 48
Jordan, A.C., 124

Kashiwado, 143
Kast, 95
Kaufmann, 68
Keith, 289, 290, 305, **389**
Kelling, 104
Kennaway, E. L., 157, 159, **385**
Kent, Stanley, 287
Klemperer, 178
Knowlton, 137

Laidlaw, 73
Lambert, 84, **384**
Lancereaux, 215
Lane, Sir Arbuthnot, 114, 119, 120, 122, 123, 126, **385**
Lang, B. T., 25
Langerhans, 139
Langley, 15, 16
Lanz, 13
Lea, 308
Leathes, 161, 244, 248, **387**
Lee, Emerson, 346
Lenhartz, 80, 84
Lewis, 297, 302, 303, 305, 352, **389, 390**
Lieb, **386**
Liebig, 195
Locke, 293
Loewi, 146
Loewy, 38
Longridge, 254
Luce, 305, **389**
Luff, 153
Lunin, 365, 366

MacCallan, 24
Mackenzie, 298, 299, 301, 309, 312, 313, **389**
Mackenzie, Hector, 12-14
Mackenzie, James, 296
Mackenzie, Wallis, **388**
Macleod, **385**
McLeod, J. J. R., **387, 388**
Maguire, 176, 179, **386**
Mahomed, 342
Malden, 167
Mann, Gustave, 355
Marshall, 36
Martin, 178, 370
Martin, Sidney, 268, 284
Mathison, 305
Matthew, 350
Mayo clinic, 135
Meltzer, 381, **391**
Metchnikoff, 257, 261, 280, 281, **388**
Meyer, 236
Michell, R. W., 314, 316, **389**
Miles, W. E., 126
Miller, 74, 108, 305, **389**
Minkowski, 136, 164, 176
Mohr, 388
Monro, 276
Moore, B., 58, 171, **386**
Moore, Craven, 45, 59, 68
Morison, 328, 360, **390**
Moynihan, 56, 60, 97
Mummery, Lockhart, 116, 341, **390**
Munk, 74
Munro, 327
Murphy, 111

Naunyn, 214
Neild, Newman, 110
Noorden, Von, 194, 201, 203, 207, 214, 216, 217, 221, 227, 228, 229, 230, 236, 237, 250, **386, 387, 388**

Oliver, 15, 350, **390**
Ophuls, 305, **389**
Opie, E. L., 135, 139, 142, **385**
Osler, 228, 348, 354, 362, **390**

Panton, 157
Paramore, **391**
Pardington, 276
Pässler, 340
Pasteur, W., 75
Paterson, **388**
Paterson, H. J., **385**
Paton, 39
Paton, E. P., 98, **385**
Paton, Noel, 141, **384**
Pavy, 137, 220, 221, 224, **387**
Pawlow, 43, 54, 63, 65, 68, 84, 128, 132, **384**
Pembrey, 239, **387**
Philpot, 30
Plant, 23
Plimmer, 156, 159, 160, **386**
Poehl, 38
Power, D'Arcy, 187, 188

Poynton, 371, **391**
Purkinje, 289

Ralfe, 183, **386**
Ranking, 276
Reach, 73
Regulin, 125
Reissner, 58
Rennie, 139, 141
Richter, 38
Riley, James, 281
Roberts, Sir William, 51, 57, 68, 167, **384**
Robson, Mayo, 134, **385**
Rohde, 293, **389**
Rolleston, 17, 20, 277, 314
Romberg, 340
Rosenfeld, 237, 248
Rosenstein, 74
Ross, G. W., 376, **386, 391**
Rothera, 233
Russell, 354, **390**
Russell, William, 340, **390**
Ryffel, 73

Saundby, 354, **390**
Savill, T. D., **390**
Schade, 171
Schäfer, 14, 15, 17, **383**
Schlesinger, 22
Schmidt, 143
Schmoll, 305, **389**
Schryver, 239
Seligmann, 38
Sendler, 305
Sequeira, 29
Sharkey, 75, **384**
Shattock, 38
Shaw, Batty, 241, **383, 387**
Short, Rendle, 27, 80, 102, 176, **384**
Sladden, A. F. S., **385**
Smith, F. J., 373
Smith, W. G., 157
Spriggs, 138, 239, 251, **384, 387**
Starling, 1, 3, 37, 42, 112, 129, 137, 318, **383, 384, 385**
Steele, 23
Stengel, 305, **389**
Stewart, Grainger, 342
Still, 110, **385**
Stockton, 151
Stokvis, 272

Takamine, 15
Tawara, 287
Taylor, Englebert, 256
Taylor, Frederick, 326, **388**
Telford, 247, **388**
Thompson, 367
Thompson, John, 109
Thorel, 289
Tirard, 187
Tribe, 241, **387**
Tritschler, 178
Tuckett, 20
Turney, 35

Umber, 78

Vaquex, 354
Verworn, 237
Voit, 369
Von Noorden. See Noorden, Von
Von Mering, 128, 136
Ville, 142
Vincent, Swale, 15, **383**

Wallis, Mackenzie, 265, 274
Watson, Chalmers, 14
Watson, Gordon, 99
Weber, Parkes, 354, 357, 358, **390**
Weintraud, 166
Wells, 368, **388, 391**
Wenkebach, 308
Wertheimer, 129
West, **388**
West, Dr. Samuel, 74, 273
White, Hale, 70
Wiggens, 22
Wilks, 26
Willcox, 58, 89, 91, 108, **384**
Wille, 145
Williams, 243
Williams, Leonard, 10, 60, 329, 333, 350, **383, 384, 390**
Williams, Whitridge, 243, **388**
Winckel, 379
Windle, 295
Windle, Davenport, 309-310
Witteing, 312
Wohlgemuth, 146
Wright, 370, 373, 375, 381
Wright, Sir A. E., 190, **386, 391**

Young, 360, **390**

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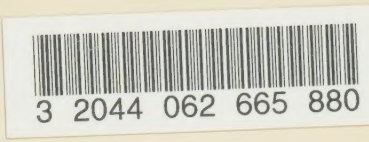
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